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Annual Progress Report

North Central Regional Aquaculture Center

Annual Progress Report

Disciplines
Agriculture | Aquaculture and Fisheries

NORTH CENTRAL
REGIONAL AQUACULTURE CENTER

ANNUAL PROGRESS REPORT

January 1997

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For the Period
September 1, 1995 to August 31, 1996

January 1997

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INTRODUCTION

The U.S. aquaculture industry continues to be one of the fastest growing sectors within U.S. agriculture, although at a lesser rate than what occurred during the 1980s. Production in 1994 reached 666 million pounds and generated approximately $751 million for producers. The impact of U.S. aquaculture is substantial accounting for approximately 181,000 jobs and generating an estimated $5.6 billion annually. Yet, anticipated growth in the industry, both in magnitude and in species diversity, continues to fall short of expectations.

Much of what is known about aquaculture science is a result of institutional attention given to our traditional capture of wild fisheries with the goal of releasing cultured fishes into public waters for enhancement of declining public stocks. Despite extensive efforts to manage wild populations for a sustained yield, as a nation we consume substantially greater amounts than we produce. Much of the United States' demand for seafood has been met by imports. The U.S. imports over 40% of its fish and shellfish and, after Japan, is the world's second largest importer of seafood. Fisheries imports are the largest contributor to the U.S. trade deficit among agricultural products, and the second largest after petroleum, among all natural resources products. The value of imported fisheries products more than doubled during the 1980s and has continued to increase in the 1990s. In fact, the $12.5 billion value for 1995 was a record. In 1995, the trade deficit was $4.2 billion for all fisheries products, $3.5 billion of which was for edible fish and shellfish.

Landings for most commercial capture fisheries species and recreational fisheries of the United States have been relatively stable during the last decade, with many fish stocks being overexploited. In this situation, aquaculture provides an opportunity to reduce the trade deficit and meet the rising U.S. demand for fish products. A strong domestic aquaculture industry is needed to increase U.S. production of fish and shellfish. This can be achieved by a partnership among the Federal Government, State and local public institutions, and the private sector with expertise in aquaculture development.

Congress recognized the opportunity for making significant progress in aquaculture development in 1980 by passage of the National Aquaculture Act (P.L. 96-362). Congress amended the National Agricultural Research, Extension, and Teaching Policy Act of 1977 (P.L. 95-113) in Title XIV of the Agriculture and Food Act of 1981 (P.L. 97-98) by granting authority to establish aquaculture research, development, and demonstration centers in the United States in association with colleges and universities, State Departments of Agriculture, Federal facilities, and non-profit private research institutions. Five such centers have been established: one in each of the northeastern, north central, southern, western, and tropical/subtropical Pacific regions of the country. The 1996 Federal Agriculture Improvement and Reform Act (FAIR) (P.L. 104-127) otherwise know as the Farm Bill, has reauthorized the Regional Aquaculture Center program at $7.5 million per annum. As used here, a center refers to an administrative center. Centers do not provide monies for brick-and-mortar development. Centers encourage cooperative and collaborative aquaculture research and extension educational programs that have regional or national application. Center programs complement and strengthen other existing research and extension educational programs provided by the U.S.

Department of Agriculture (USDA) and other public institutions. As a matter of policy, centers implement their programs by using institutional mechanisms and linkages that are in place in the public and private sector.

The mission of the Regional Aquaculture Centers (RACs) is to support aquaculture research, development, demonstration, and extension education to enhance viable and profitable U.S. aquaculture production which will benefit consumers, producers, service industries, and the American economy.

The North Central Regional Aquaculture Center (NCRAC) was established in February 1988. It serves as a focal point to assess needs, establish priorities, and implement research and extension educational programs in the twelve state agricultural heartland of the United States which includes Illinois, Indiana, Iowa, Kansas, Michigan, Missouri, Minnesota, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. NCRAC also provides coordination of interregional and national programs through the National Coordinating Council for Aquaculture (NCC). The council is composed of the RAC directors and USDA aquaculture personnel.

ORGANIZATIONAL STRUCTURE

Michigan State University (MSU) and Iowa State University (ISU) work together to develop and administer programs of NCRAC through a memorandum of understanding. MSU is the prime contractor for the Center and has administrative responsibilities for its operation. The Director of NCRAC is located at MSU. ISU shares in leadership of the Center through an office of the Associate Director who is responsible for all aspects of the Center's publications, technology transfer and outreach activities.

At the present time the staff of NCRAC at MSU includes Ted R. Batterson, Director and Liz Bartels, Executive Secretary. The Center Director has the following responsibilities:

- Serving as executive secretary to the Board of Directors, responsible for preparing agenda and minutes of Board meetings;
- Serving as an ex-officio (non-voting) member of the Technical Committee and Industry Advisory Council;
- Coordinating the development of research and extension plans, budgets, and proposals;
- Coordinating and facilitating interactions among the Administrative Center, Board of Directors, Industry Advisory Council, and Technical Committee;
- Monitoring research and extension activities;
- Arranging for review of proposals for technical and scientific merit, feasibility, and applicability to priority problems and preparing summary budgets and reports as required;
- Recruiting other Administrative Center staff as authorized by the Board of Directors;
- With assistance of the Economics and Marketing Work Group, Technical Committee, or others preparing a summary of regional aquaculture, including production statistics and sales, and identifying technical, financial, and institutional constraints to expanding production. The summary shall include sections addressing established industries, development industries, and opportunities for new product development, and recommended research needs;

- Maintaining liaison with other RACs; and
- Serving on the NCC.

At the present time the staff of NCRAC's Office for Publications and Extension Administration at ISU includes Joseph E. Morris, Associate Director and Glenda Dike, Secretary. The Associate Director has the following responsibilities:

- Serving as head of Publications for NCRAC, including editor of the Center's newsletter;
- Serving as the NCRAC liaison with national aquaculture extension programs, including in particular, extension programs of the other four USDA RACs; and
- Serving as a member of NCRAC's Extension Executive Committee.

The Board of Directors (BOD) is the primary policy-making body of the NCRAC. The BOD has established an Industry Advisory Council (IAC) and Technical Committee (TC). Membership of the BOD consists of two persons from the IAC (the chair and an at-large member), a representative from the region's State Agricultural Experiment Stations and Cooperative Extension Services, a member from a non-land grant university and representatives from the two universities responsible for the center: Michigan State and Iowa State. The IAC is composed of representatives from each state's aquaculture association and six at-large members appointed by the BOD who represent various sectors of the aquaculture industry and the region as a whole. The TC is composed of a sub-committee for Extension (TC/E) and a subcommittee for Research (TC/R). Directors of the Cooperative Extension Service within the North Central Region appoint representatives to the TC/E. The TC/R has broad regional make-up and is composed of scientists from universities and state agencies with varied aquacultural expertise who are appointed by the BOD. Each sub-committee of the TC has a chairperson who serves as an ex-officio member of the BOD.

NCRAC functions in accordance with its *Operations Manual* which is periodically amended and updated with BOD approval. It is an evolving document that has changed as the Center's history lengthens. It is used for the development of the cooperative regional aquaculture and extension projects that NCRAC funds.

ADMINISTRATIVE OPERATIONS

Since inception of NCRAC February 1, 1988, the role of the Administrative Center has been to provide all necessary support services to the BOD, IAC, TC, and project work groups for the North Central Region as well as representing the region on the NCC. As the scope of the NCRAC programs expand, this has entailed a greater work load and continued need for effective communication among all components of the Center and the aquaculture community.

The Center functions in the following manner.

- After BOD approval of Administrative Center costs, the Center submits a grant to USDA/CSREES/Grants Management Branch for approval. To date the Center has received nine grants from USDA for FY88 (Grant #88-38500-3885), FY89 (Grant #89-38500-4319), FY90 (Grant #90-38500-5008), FY91 (Grant #91-38500-5900), FY92 (Grant #92-38500-6916), FY93 (Grant #93-38500-8392), FY94 (Grant #94-38500-0048), FY95 (Grant #95-38500-1410), and FY96 (Grant #96-38500-2631) with monies totaling $6,440,981. Currently, five grants are active (FY92-96); the first four grants (FY88-91) have terminated.

- The Center annually coordinates a program planning meeting which sets priorities for the next funding cycle and calls for regional workshops to develop project outlines to address priority problem areas.
- Work Groups, which are formed at the workshops, submit project outlines to the Center. The projects are peer reviewed by experts from both within and outside the region.
- The BOD, using reviewers' responses, decides which projects are to be approved and funding levels. The Center conveys BOD decisions to all Project Work Groups. Those that are approved for funding are asked to submit revised project outlines incorporating BOD and reviewers' comments.
- The Center then submits the revised project outlines as a Plan of Work (POW) to USDA for approval.
- Once a POW is approved by USDA, the Center then prepares subcontracts for each participating institution. The Center receives all invoices for subcontractual agreements and prepares payment vouchers for reimbursement. Thus, the Center staff serve as fiscal agent for both receiving and disbursing of funds in accordance with all terms and provisions of the grants.

To date, the Center has funded or is funding 39 projects through 224 subcontracts from the nine grants received. Funding for all Center supported projects, except for Publications and development of an Aquaculture Situation and Outlook Report, is summarized in Table 1 below (pages 7-8).

During this reporting period, the Publications Office at ISU produced and distributed a number of publications including fact sheets, technical bulletins, videos, and the Center's newsletter. A complete list of all publications from this office is included in Appendix A under Extension.

Other areas of support by the Administrative Office during this reporting period included: monitoring research and extension activities and developing progress reports; facilitating a program review of the Center (see Appendix B which contains the reviewers' summary report); developing liaisons with appropriate institutions, agencies and clientele groups; preparing, in coordination with the other RACs, both written and oral testimony for the U.S. House Appropriations subcommittee on Agriculture, Rural Development, Food and Drug Administration, and Related Agencies hearing in Washington, D.C.; participating in the NCC; numerous oral and written presentations to both professional and lay audiences; working with other fisheries and aquaculture programs throughout the North Central Region; and in conjunction with the Aquaculture Network Information Center (AquaNIC) creating a NCRAC web site (http://www.ansc.purdue.edu/aquanic/ncrac.htm).

PROJECT DEVELOPMENT

A joint Program Planning meeting of the BOD, IAC, and TC is held every year in the early winter. The IAC, with input from the TC, generates a list of priority areas for consideration by the BOD. Using their recommendation as guidelines, the BOD then selects priority areas for which project outlines will be developed. The BOD also specifies a maximum funding level for each priority area. Problem statements and objectives are then developed for each priority area by IAC and TC members at the

Program Planning meeting. For projects with more than one objective, the IAC ranks the objectives by priority. The problem statement and objective(s) are then included in a workshop announcement that is broadly distributed throughout the North Central Region. The workshops are one-day events to establish a work group that will develop a project outline over the summer months. Work group members will be those who have demonstrated that they have the expertise and facilities for undertaking the proposed work in regard to a particular objective or objectives. The proposed work cannot deviate from the objective or objectives included in the workshop announcement. The work group elects a chair and secretary. The chair is responsible for submitting the project outline to the NCRAC Director; the secretary is responsible for preparing minutes from the workshop that are distributed to all attendees. All project outlines are peer reviewed. The reviewers' comments are used by the BOD in making the final selection of projects and level of funding at the following year's annual Program Planning meeting. All work group members are apprised of the BOD decisions. Revisions of projects approved by the BOD are submitted by the work group chair to the NCRAC Director. The revised project outlines are then included in a POW that is submitted to USDA. Upon approval by USDA, the Center issues subcontracts to the funded work group members.

TIME FRAME

- Program Planning meeting: early winter.
- Workshops: late-spring, early summer.
- Project outlines developed over the summer by work group members who participated in the workshops. These project outlines are then submitted to the Center in the fall and peer reviewed.
- The Board of Directors at the following year's Program Planning meeting selects the projects to be funded.
- Project outline revised and submitted to the Center by May.
- Revised projects are then submitted in June as a POW (or an amendment to a POW) to USDA for approval. Once approved by USDA subcontracts are let by the Center with a start date of September 1.

By following this procedure, it takes approximately 18 months from the time of identifying a priority area until inception of a project to address the issue in question.

WORKSHOPS

The purpose of the workshops is to bring together those who are best qualified to work on project objectives by virtue of a demonstrated record of expertise and access to facilities required in the project. These people form a work group for the purpose of writing a project outline to address the problem in question. The following criteria typically apply to those projects that are funded by NCRAC.

- Involves participation by two or more states in the North Central Region;
- requires more scientific manpower, equipment, and facilities than generally available at one location;
- approach is adaptable and particularly suitable for inter-institutional cooperation resulting in better use of limited resources and a saving of funds;
- will complement and enhance ongoing extension and research activities by participants, as well as offer potential for expanding these programs;
- is likely to attract additional support for the work which is not likely to occur through other programs and mechanisms;
- is sufficiently specific to promise

significant accomplishments in a reasonable period to time (usually up to 2 years);
- can provide the solution to a problem of fundamental importance or fill an information gap;
- can be organized and conducted on a regional level, assuring coordinated and complementary contributions by all participants.

The NCRAC program pays no overhead to participating institutions nor tuition remission, has no brick-and-mortar money, and relies on in-place salaried personnel, equipment, and facilities to carry out the projects. Due to the collaborative and cooperative nature of these regional projects, no one individual or institution receives a significant portion of the total project funds.

PROJECT REPORTING

As indicated in Table 1, the Center has funded a number of projects for many of the project areas. For example, there have been five separately funded projects in regard to Extension and six for Walleye. Project outlines have been written for each separate project within an area, or the project area itself if only one project. These project outlines have been submitted in POWs or amendments to POWs for the grants as indicated in Table 1. Many times, the projects within a particular area are merely continuations of previously funded activities; while at other times they are addressing new objectives. Presented below are Progress or Termination Reports for all projects that were underway or completed during the period September 1, 1995 to August 31, 1996.

All publications, manuscripts, or papers for all funded NCRAC project areas are listed in Appendix A.

Table 1. North Central Regional Aquaculture Center funded projects.

Project Area	Project Number	Duration	Funding Level	Grant Number
Extension	1		$39,221	88-38500-3885
	2	5/1/89-4/30/91	$68,389	89-38500-4319
	3		$94,109	91-38500-5900
	4	3/17/90-8/31/91	$110,129	91-38500-5900
	5		$10,875	92-38500-6916
		9/1/91-8/31/93	$25,725	95-38500-1410
			$348,448	
		9/1/93-8/31/95		
		9/1/95-8/31/97		
Economics and Marketing	1		$127,338	88-38500-3885
		5/1/89-12/31/91	$34,350	89-38500-4319
	2		$53,300	91-38500-5900
	3		$40,000	93-38500-8392
		9/1/91-8/31/93	$254,988	
		9/1/93-8/31/95		
Yellow Perch	1		$76,957	88-38500-3885
		5/1/89-8/31/91	$85,723	89-38500-4319
	2		$92,108	90-38500-5008
	3		$99,997	91-38500-5900
	4	6/1/90-8/31/92	$150,000	93-38500-8392
	5		$200,000	95-38500-1410
		9/1/91-8/31/93	$704,785	
		9/1/93-8/31/95		
		9/1/95-8/31/97		
Hybrid Striped Bass	1		$68,296	88-38500-3885
		5/1/89-8/31/91	$68,114	89-38500-4319
	2		$101,000	90-38500-5008
	3		$96,550	91-38500-5900
	4	6/1/90-8/31/92	$168,000	93-38500-8392
	5		$160,000	95-38500-1410
		9/1/91-8/31/93	$661,960	
		9/1/93-8/31/95		
		9/1/95-8/31/97		
Walleye	1		$177,517	89-38500-4319
	2	5/1/89-8/31/91	$111,657	90-38500-5008
	3		$109,223	91-38500-5900
	4	6/1/90-8/31/92	$75,000	89-38500-4319
	5		$150,000	93-38500-8392
	6	9/1/91-8/31/92	$117,897	94-38500-0048
			$57,103	95-38500-1410
		9/1/92-8/31/93	$798,397	
		9/1/93-8/31/95		
		9/1/95-8/31/97		

Project Area	Project Number	Duration	Funding Level	Grant Number
Sunfish	1 2 3 4	6/1/90-8/31/92 9/1/92-8/31/94 9/1/94-8/31/96 9/1/96-8/31/98	$130,758 $149,799 $174,999 $200,000 $655,556	90-38500-5008 92-38500-6916 94-38500-0048 96-38500-2631
Salmonids	1 2 3	6/1/90-8/31/92 9/1/92-8/31/94 9/1/94-8/31/96	$9,000 $120,799 $149,997 $200,000 $479,796	89-38500-4319 90-38500-5008 92-38500-6916 94-38500-0048
NCR Aquaculture Conference	1	6/1/90-12/31/91	$7,000	90-38500-5008
National Aqua. Extension Workshop	1	10/1/91-9/30/92	$3,005	89-38500-4319
Crayfish	1	9/1/92-8/31/94	$50,000	92-38500-6916
Baitfish	1	9/1/92-8/31/94	$62,000	92-38500-6916
Wastes/Effluents	1 2	9/1/92-8/31/94 9/1/96-8/31/98	$153,300 $100,000 $253,300	92-38500-6916 96-38500-2631
Aquaculture Drugs (INADs/NADAs)	1	9/1/93-8/31/94 9/1/93-8/31/94 9/1/95-8/31/96 9/1/95-8/31/96	$2,000 $5,000 $6,669 $3,331 $17,000	90-38500-5008 94-38500-0048 92-38500-6916 95-38500-1410
Tilapia	1	9/1/96-8/31/98	$120,000	96-38500-2631

PROJECT TERMINATION OR PROGRESS REPORTS

EXTENSION

Progress Report for the Period
May 1, 1989 to August 31, 1996

NCRAC FUNDING LEVEL: $328,923 (May 1, 1989 to August 31, 1996)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
James E. Ebeling	Ohio State University	Ohio
Donald L. Garling	Michigan State University	Michigan
Jeffrey L. Gunderson	University of Minnesota	Minnesota
F. Robert Henderson	Kansas State University	Kansas
John Hochheimer	Ohio State University	Ohio
Anne R. Kapuscinski	University of Minnesota	Minnesota
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Ronald E. Kinnunen	Michigan State University	Michigan
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
David J. Landkamer	University of Minnesota	Minnesota
Charles Lee	Kansas State University	Kansas
Joseph E. Morris	Iowa State University	Iowa
Kenneth E. Neils	Kansas State University	Kansas
Robert A. Pierce II	University of Missouri	Missouri
Daniel A. Selock	Southern Illinois University-Carbondale	Illinois
LaDon Swann	Purdue University	Indiana/Illinois
Administrative Advisor:		
David C. Petritz	Purdue University	Indiana

PROJECT OBJECTIVES

(1) Strengthen linkages between North Central Regional Aquaculture Center (NCRAC) research and extension work groups.

(2) Enhance the North Central Region (NCR) extension network for aquaculture information transfer.

(3) Provide in-service training for Cooperative Extension Service, Sea Grant Advisory Service, and other landowner assistance personnel.

(4) Develop and implement aquaculture educational programs for the NCR.

(5) Develop aquaculture materials for the NCR including extension fact sheets, bulletins, manuals/guides, and instructional video tapes.

ANTICIPATED BENEFITS

The NCRAC Extension Work Group will promote and advance commercial aquaculture in a responsible fashion through an organized education/training outreach program. The primary benefits will be:

- increased public awareness through publications, short courses, and conferences regarding the potential of

aquaculture as a viable agricultural enterprise in the NCR;
- technology transfer to enhance current and future production methodologies for selected species, e.g., walleye, hybrid striped bass, yellow perch, salmonids, and sunfish, through hands-on workshops and field demonstration projects;
- improved lines of communication between interstate aquaculture extension specialists and associated industry contacts; and
- an enhanced legal and socioeconomic atmosphere for aquaculture in the NCR.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Due to the efforts of aquaculture extension personnel in the NCR, NCRAC's Board of Directors formally adopted guidelines for extension's involvement in all NCRAC-funded projects. These guidelines integrate research and extension activities so that extension service personnel can better serve their clientele groups.

In addition, aquaculture Extension Work Group members have:

- Served as extension liaison, if not an active researcher, for every funded NCRAC project.
- Assisted in writing and developing the NCRAC Walleye Culture Manual that was edited by Bob Summerfelt of Iowa State University.
- Assisted with the planning, promotion, and implementation of the hybrid striped bass, walleye and yellow perch workshops held throughout the region.
- Helped conduct a survey of crayfish producers in the NCR and completed a report on *Orconectes immunis* for inclusion in the Crayfish Work Group report.
- Provided the NCRAC Economics and Marketing Work Group with information relevant to that group's efforts to develop cost of production budgets and expected revenues for the commercial production of food-sized hybrid striped bass, walleye, and yellow perch in the NCR.
- Participated as Steering Committee members for a regional public forum regarding the National Aquaculture Development Plan of 1996.
- Assisted NCRAC in obtaining information on the 1995 status of aquaculture in the NCR. The information will be used to develop NCRAC's regional aquaculture situation and outlook (S&O) report. Extension specialists often coordinated the effort to develop a cover letter, prepare a mailing list and send the survey out and to follow up to assure a high response rate.
- Conducted educational programs for the Wisconsin Aquaculture Association on non-indigenous aquatic nuisance species and implications for aquaculture as well as participating in the annual meeting of the Great Lakes Fish Health Committee providing input as it relates to aquaculture.

OBJECTIVE 2

The demand for aquaculture extension education programs cannot be met by the few specialists in the NCR (4.0 FTE). Networking of specialists and Cooperative Extension Service (CES) designated contacts has maximized efficiency of education programs and minimized duplication. The NCRAC Extension Project is designed to assess and meet the information needs of the various clientele groups through cooperative and coordinated regional educational programming. In fact, individual state extension contacts often respond to 10-15 calls per month from outside their respective state as well as interacting with colleagues with mutual concerns related to developing aquaculture activities.

Prior to mid-1994 little coordination of international aquaculture information sharing existed. National and international agencies producing information could only be obtained by contacting the respective sources of this information. Also, individual CES personnel relied heavily on information produced by individual states or through regional cooperative projects. As Internet access extended beyond educational institutions and governmental agencies, a clear need developed to utilize the Internet to reach a much broader audience. In the age of an "information overload" the need for a centralized gateway to the ever increasing number of aquaculture resources in electronic format was apparent.

The development of the Aquaculture Information Network Center (AquaNIC) has been instrumental in reaching the public with valuable and timely information. It has been funded, in part, by NCRAC and has currently over 4,000 contacts per month from more than 50 countries to this web site. AquaNIC receives direction from a national steering committee from public and private sector aquaculture. AquaNIC began on a Gopher Server in July 1994 and moved to a World Wide Web server in January 1996. AquaNIC (http://www.ansc.purdue.edu/aquanic/) houses more than 1,650 extension publications, governmental documents, image files, comprehensive e-mail lists, newsletters, calendars, job announcements, and résumés. In addition, AquaNIC has 190 pointers to other aquaculture and fisheries related web sites. Ongoing promotional campaigns through mouse pads and access information cards has increased the level of awareness of this new resource available to the world aquaculture industry. It is the gateway to the world's electronic resources in aquaculture including the Regional Aquaculture Centers. AquaNIC also serves as the home of NCRAC's web site (http://www.ansc.purdue.edu/aquanic/ncrac.htm) which was developed in conjunction with NCRAC administrative staff and the Illinois-Indiana Sea Grant Program. The web site provides electronic versions of NCRAC extension publications, directories, operations manuals and newsletters.

Aquaculture handbooks have been developed and distributed to each NCRAC designated aquaculture extension specialist and selected CES and Sea Grant field staff member.

As with any organization, there have been changes in NCRAC extension personnel since the inception of the project. Landkamer was the primary aquaculture extension contact for Minnesota. However, he left the university and Kapuscinski became the primary contact person until 1992 when Gunderson assumed that responsibility. In 1994 there were two changes: in Kansas, Neils replaced Henderson and in Illinois, Kohler replaced Selock. There continues to be changes in NCRAC extension personnel since the inception of the project; Hochheimer has replaced Ebeling in Ohio while Lee replaced Neils in Kansas in 1996.

OBJECTIVE 3

In-service training for CES and Sea Grant personnel and other landowner assistance personnel have been held in most of the states in the region. Training has been in the areas of basic aquaculture and safe seafood handling including HACCP (Hazard Analysis

Critical Control Point).

OBJECTIVE 4

A number of workshops, conferences, videos, field-site visits, hands-on training sessions, and other educational programs have been developed and implemented.

There have been workshops on general aquaculture, fish diseases, commercial recirculation systems, aquaculture business planning, crayfish culture, pond management, yellow perch and hybrid striped bass culture, rainbow trout production, in-service training for high school vocational-agricultural teachers and polyploid induction in sunfish held in the region.

Two North Central Aquaculture Conferences (NCAC) have been held. The first in Kalamazoo, Michigan was held in March 1991. The second was held in February 1995 in Minneapolis, Minnesota. These regional meetings were attended by hundreds of individuals including persons from Canada. The next conference is scheduled for February 1997 in Indianapolis, Indiana.

On April 10, 1993, over 700 viewers from 35 states and Canada watched the first national interactive teleconference on aquaculture, "Investing in Freshwater Aquaculture," that was broadcast from Purdue University. It was a televised satellite broadcast for potential fish farmers. The program consisted of 10 five- to seven-minute video tape segments which addressed production aspects of channel catfish, crayfish, rainbow trout, hybrid striped bass, tilapia, yellow perch, baitfish, and sportfish. A set of course materials was available prior to the program. Three times during the program, a question and answer period was available to the audience through a toll free telephone number. Questions not answered during the program were answered by mail afterwards. The entire teleconference is available as a videotape from NCRAC's Publications Office as well as two other videotapes by the University of Nebraska-Lincoln that are reprises of the broadcast.

OBJECTIVE 5

Numerous fact sheets, technical bulletins, and videos have been written or produced by various participants of the Extension Work Group. These are listed in the Appendix.

WORK PLANNED

Efforts will continue in regard to strengthening linkages between research and extension work groups as well as enhancing the network for aquaculture information transfer. Participants will also continue to provide in-service training for CES, Sea Grant, and other landowner assistance personnel. Educational programs and materials will be developed and implemented. This includes development of a sunfish culture guide, yellow perch culture guide and videos, hybrid striped bass culture guide, a publication on fee-fishing (sunfish), tilapia culture information packet and a publication on yellow perch culture in flowing water systems.

Additional workshops developed and hosted by state extension contacts will be advertised in surrounding states to take advantage of the NCRAC extension network and the individual expertise of Extension Work Group participants.

Several additional NCRAC fact sheets, technical bulletins, and videos will be developed by various Work Group members.

IMPACTS

- In-service training for CES and Sea Grant personnel has enabled those professionals to respond to initial, routine aquaculture questions from the general public.

- Development of aquaculture education programs for the NCR has provided "hands-on" opportunities for prospective and experienced producers. Approximately 5,000 individuals have attended workshops or conferences organized and delivered by the NCRAC Extension Work Group. Clientele attending regional workshops learned of aquaculture development strategies in other areas of the country and acquired information which was of direct use to their own enterprises. Education programs also created situations where problems encountered by producers were expressed to extension personnel who later relayed them to researchers at NCRAC work group meetings for possible solutions through the research effort.
- Fact sheets, technical bulletins, and videos have served to inform a variety of clients about numerous aquaculture practices for the NCR. For instance, "Making Plans for Commercial Aquaculture in the North Central Region" is often used to provide clients with initial information about aquaculture, while species specific publications on walleye, trout, and catfish have been used in numerous regional meetings and have been requested by clients from throughout the United States. Publications on organizational structure for aquaculture businesses, transportation of fish in bags, and others are beneficial to both new and established aquaculturists. In a 1994 survey, NCRAC extension contacts estimated that NCRAC publications were used to address approximately 15,000 client questions annually.
- NCRAC extension outreach activities have helped to foster a better understanding and awareness for the future development of aquaculture in the region.
- In the brief time since AquaNIC began more than 25,000 people from 49 countries have chosen to use AquaNIC as an alternative to or in conjunction with traditional means of obtaining information. Primary users by countries are: U.S. (40%), Canada (5%), Australia (3%), and the United Kingdom (2%). As a gateway to electronic resources in aquaculture, AquaNIC has increased the timeliness and variety of information available to outreach educators, governmental agencies, and individual users while more effectively utilizing existing personnel resources. AquaNIC can be accessed anytime and, therefore, alleviates the challenges associated with office hours, time zones or weekends. Several groups have recognized the benefits AquaNIC provides to the world aquaculture industry and have established long-term partnerships with AquaNIC to assist them in distribution of their resources. Key groups using AquaNIC to house their web sites include: the World Aquaculture Society, NCRAC, Indiana Aquaculture Association, and the Illinois Aquaculture Industry Association.

PUBLICATIONS, MANUSCRIPTS, WORKSHOPS, AND CONFERENCES

See Appendix A.

SUPPORT

YEARS	NCRAC-USDA	OTHER SUPPORT	TOTAL SUPPORT

	FUNDING						
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1989-90	$39,221	$66,992				$66,992	$106,213
1990-91	$68,389	$70,065				$70,065	$138,454
1991-93	$94,109	$152,952				$152,952	$247,061
1993-95	$110,129	$198,099		$250,000	$55,000	$503,099	$613,228
1995-96	$17,075	$70,968				$70,968	$88,043
TOTAL	$328,923	$559,076		$250,000	$55,000	$864,076	$1,192,999

ECONOMICS AND MARKETING

Progress Report for the Period
September 1, 1993 to August 31, 1996

NCRAC FUNDING LEVEL: $40,000 (September 1, 1993 to August 31, 1996)

PARTICIPANTS:

Susan B. Kohler	Southern Illinois University-Carbondale	Illinois
Marshall A. Martin	Purdue University	Indiana
Patrick D. O'Rourke	Illinois State University	Illinois
Jean R. Riepe	Purdue University	Indiana
Extension Liaisons:		
Donald L. Garling	Michigan State University	Michigan
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
LaDon Swann	Purdue University	Indiana

PROJECT OBJECTIVE

Develop cost of production budgets and expected revenues for the raising of yellow perch, walleye and hybrid striped bass (HSB) on farms in the North Central Region (NCR).

ANTICIPATED BENEFITS

The overall goal of this collaborative project was to enhance walleye, yellow perch and HSB production by developing enterprise budgets for various production systems for these species in the NCR. This supports the mission of the North Central Regional Aquaculture Center (NCRAC), especially by conducting research "for the enhancement of viable and profitable commercial aquacultural production in the United States for the benefit of producers, consumers, and the American economy."

The cost of production and budgeting components of this project offer the potential to help in identifying production systems for walleye, yellow perch and HSB most likely to be commercially viable in the NCR. Information on production costs is quite limited for these species, especially walleye and yellow perch. Enterprise budgets for real and prototype systems will enable producers or potential producers to assess the expected costs for their own operation, for a new operation, or for increased production in their present operation in an objective and comprehensive manner.

This project will benefit the aquaculture industry in the NCR in several ways, even though there are some limitations in using these budgets given the "emerging" status of the industry and the small number of commercial producers in these three species:

- First, objectively developed cost information is typically more accurate than subjectively developed cost information or no information on costs at all. These budgets will give producers an idea of how enterprise budgets should be organized, what types of data need to be collected, and why good record keeping is essential. The production values and relationships upon which the cost structure are based, while not standardized in the industry, should serve as a rough rule-of-thumb by which aquacultural producers can gauge their management skills.

- Second, enterprise budgets are an excellent management tool and are the cornerstone for financial analysis of aquaculture operations for producers and investors. These budgets may stimulate potential and current aquacultural producers to put together budgets and analysis for their own unique enterprises.
- Third, enterprise budgets are also the cornerstone for sensitivity analysis (yet another management tool). Undertaking sensitivity analysis will enable economists, producers and potential producers to better understand the relative importance of cost and production items in the budget and the impact on profitability.
- Finally, realizing that the budgets produced under the auspices of this project will not be the final, definitive budgets for production of these species in the NCR, they will serve as a solid starting base from which to better understand the potential profitability of alternative species, production systems, life stages, etc.

In a more indirect way, the enterprise budgets will accomplish two other important things.

- One, the budgets may help guide research and extension decisions concerning HSB, walleye and yellow perch by NCRAC work group participants, the Industry Advisory Council (IAC), the Board of Directors (BOD), and the supporting committees.
- Second, the budgets will provide an opportunity for the economists and other personnel developing the budgets to interact with aquaculture producers, researchers, and extension personnel in the NCR. This type of interdisciplinary interaction is vital for the improved understanding and communication of all vital aspects of aquaculture in the NCR.

Economic feasibility analysis will help producers evaluate technical advances in fish production. This contribution is critical as a guide to future research funding in the various species and production systems suitable for commercial production. The distribution of research results from this project will provide a structured and objective framework for profitability and financial analysis of HSB, walleye and yellow perch aquaculture systems for producers, financial institutions, and others.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

HYBRID STRIPED BASS

Kohler has compiled a review of the literature on HSB production and production costs. The literature reviewed is summarized in an annotated bibliography. This bibliography will be available to anyone needing the information.

Kohler has developed HSB cost of production estimates based on six recent published reports on HSB production. These estimated production costs were presented at the NCRAC Hybrid Striped Bass Workshop in November 1995.

WALLEYE

O'Rourke and Illinois State University graduate students continued an extensive walleye production and culture literature review. The primary focus of the literature review was to evaluate research findings that might be useful in ascertaining the cost of production for walleye fingerlings and food-sized fish under intensive and extensive culture regimes. Very little economic research was found and even less was found that was documented well enough to be useful.

Work has advanced on identifying and analyzing the cost of production for food-sized walleye in intensive culture systems. The second M.S. thesis on walleye to come from this project was officially finished in December 1995. It reported on an economic feasibility analysis of a tank based intensive food-sized walleye system.

YELLOW PERCH

Riepe's analysis of yellow perch production in ponds and cages is reported in NCRAC Extension Fact Sheet #111 and NCRAC Extension Technical Bulletin #111, both ready for release. While developing cost estimates for yellow perch aquaculture, Riepe investigated feed and fingerling prices and procurement with various suppliers. A fact sheet on managing feed costs was developed and is in final review by Riepe as a NCRAC Extension Fact Sheet.

WORK PLANNED

The distribution of research results from this project is proceeding, primarily for the walleye species. The research on cost of production in tank culture systems for fingerlings and food sized walleye will be organized in fact sheet or technical bulletin format for release to producers, financial institutions and others. Riepe will complete the review of the fact sheet on managing feed costs. This is expected to be published as a NCRAC Extension Fact Sheet.

IMPACTS

Kohler and O'Rourke presented the review of HSB production costs as well as profitability and volume-cost business analysis tools at the NCRAC Hybrid Striped Bass Workshop in November 1995. The information developed and presented is anticipated to be directly useful to the attendees (producers and potential producers) as they consider their own operations and intentions in light of the cost data and analytical tools presented.

This project has already benefited the aquaculture industry in the NCR through the workshop presentations. As a result of this NCR project, economists have been able to develop and deliver presentations on economic issues in aquaculture production to current and potential aquacultural producers. These presentations and the publications which follow may reduce the impacts of uninformed investment decisions by current and potential aquaculture entrepreneurs.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix A.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1993-95	$40,000	$59,683				$59,683	$99,683
1995-96	$0	$0				$0	$0
TOTAL	$40,000	$59,683				$59,683	$99,683

YELLOW PERCH

Progress Report for the Period
September 1, 1993 to August 31, 1996

NCRAC FUNDING LEVEL: $257,086 (September 1, 1993 to August 31, 1996)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Paul B. Brown	Purdue University	Illinois
Konrad Dabrowski	Ohio State University	Ohio
Donald L. Garling	Michigan State University	Michigan
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Extension Liaison:		
Donald L. Garling	Michigan State University	Michigan
Non-funded Collaborators:		
Harlan Bradt, etc.	Coolwater Farms, LLC, Cambridge	Wisconsin
William Hahle	Pleasant Valley Fish Farm, McCook	Nebraska
John Hyink/John Wolf	Alpine Farms/Glacier Springs Trout Hatchery	Wisconsin
Dave Smith	Freshwater Farms of Ohio, Inc., Urbana	Ohio
Michael Wyatt	Sandhills Aquafarm, Keystone	Nebraska
Nebraska Game & Parks Commission	Calamus State Fish Hatchery, Burwell	Nebraska
Forrest Williams	Bay Port Aquaculture, Inc., West Olive	Michigan

PROJECT OBJECTIVES

(1) Continue to improve larval rearing techniques by developing and evaluating different starter diets in relation to size at transfer to formulated feeds under selected environmental conditions.

(2) Continue to improve pond fingerling production through examination of in-pond feeding techniques using physical/chemical attractants and improved harvesting strategies for different sizes of fingerlings from various types and sizes of ponds.

(3) Continue development of extension materials and workshops emphasizing practical techniques coinciding with production events to meet the needs of established and potential yellow perch culturists through on-site presentations at two or more locations in different parts of the region.

ANTICIPATED BENEFITS

This project addresses priority needs identified by the North Central Regional Aquaculture Center (NCRAC) Industry Advisory Council (IAC) for advancing yellow perch aquaculture in the North Central Region (NCR). The IAC has indicated that one major constraint that presently limits perch aquaculture is the lack of reliable methods of producing perch fingerlings habituated to formulated feeds. In addition, there is a continuing need to provide producer training on key aspects of perch aquaculture, and to transfer advances in perch culture technology to the public sector.

The information generated by these projects will greatly assist perch producers in their efforts to reliably raise the large number of perch fingerlings needed by the industry. Improvements in pond fingerling techniques will immediately increase the availability of fingerlings to the industry because almost all fingerlings currently available are produced in ponds. Research on the effect of spawner size on larval size and on starter diet formulation for yellow perch will improve intensive fry rearing techniques and decrease the dependence on live feeds. Laying the foundation for use of one of the more potent and proven legal flavor additives for fish requires quantifying two critical nutritional requirements for yellow perch; the total sulfur amino acid and choline requirements. These values alone are beneficial in terms of developing a diet for yellow perch and provide the foundation for evaluation of betaine as a flavor additive in diets.

Extension activities will continue to promote and advance yellow perch culture through expanded outreach, education, and training programs. Additional extension materials (bulletins, fact sheets, audiovisual materials) developed by the NCRAC Yellow Perch and Extension Work Groups and a series of hands-on workshops and field demonstrations will transfer current technology to established and potential fish farmers, and increase public awareness of the potential of yellow perch aquaculture as a viable agricultural enterprise in the NCR. In addition, this project will develop improved technologies for certain key facets of yellow perch aquaculture. Finally, the results of experiments incorporated into this proposal will immediately help fish farmers improve the production efficiency of yellow perch.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

As an integral component of this project, private producers have cooperated by providing facilities, fish, feed, day-to-day husbandry, and routine data collection. At its inception, this project included the participation of eight different private fish farms in various parts of the NCR. Participating university researchers provided project oversight on experimental design, advice or direct assistance with the technical set-up of any specialized experimental systems, supervision and assistance on critical end-point data collection, and analyses of results.

In Year 1 of the project (September 1, 1993 to August 31, 1994), significant progress was made at certain sites at testing selected research-based production technologies. Accordingly, from an extension perspective, the project is successfully building and/or expanding working relationships between NCRAC researchers and certain regional fish farmers, testing various research-based technologies under practical production conditions, transferring knowledge from academia to the private sector, and identifying private producers who are both capable and willing to sustain a collaborative technology evaluation and demonstration effort. Several of the original private-sector collaborators have either met or have worked hard to meet their project commitments.

OBJECTIVE 1

Researchers at Michigan State University (MSU) directed their efforts in 1996 towards studying the effects of female spawner size on the size of eggs and fry. Spawning stock were collected from the outer Saginaw Bay, Lake Huron and transported to Bay Port Aquaculture, West Olive, Michigan. Bay Port workers held the fish until they could be manually spawned. Eggs were sampled from females divided into six size classes in 25 mm (1 in) increments from 200 to 350 mm (7.8 to 13.8 in).

Subsamples of eggs were collected from the ends and center of each ribbon. Approximately one gram of eggs from each subsample was weighed and fixed in Stockard's solution for subsequent measurements. The ribbon segments were fertilized and placed into specially designed incubator trays and incubated in well water at 11.5°C (52.7°F). Nine days after fertilization, measurements of larval mouth gape (height and width) and total length were taken using a dissecting microscope in conjunction with the Optimas imaging system, BioScan™. The data is currently being analyzed. Preserved egg samples were used to determine the number of eggs/g and 25 eggs were measured along the long axis of the egg outer diameter and the yolk membrane. Preliminary evaluation of egg size indicates a positive relationship with the length of the maternal parent.

A sulfur amino acid requirement study is underway at Purdue University (Purdue) and should be completed by December 1996. Through four weeks, fish fed 1.0% methionine are growing better than fish fed lower concentrations in the diet.

Studies at Ohio State University (OSU) have been designed to evaluate the use of pancreatic enzymes and a digestive tract neurohormone, bombesin, in the diets offered to 0.6 g (0.02 oz) yellow perch. Perch fry were raised initially in ponds (Ohio Valley Fisheries, Inc.) and were transferred to an indoor facility and accustomed to an artificial commercial diet (Ziegler). Studies on three experimental diets and one commercial diet fed to triplicate groups of yellow perch are being conducted using 40 L (10.6 gal) glass tanks at OSU. Experimental diet 1 is supplemented with either pancreatic digestive enzymes (PD), diet 2 with bombesin and PD, and diet 3 with nothing. Results indicated no significant differences between treatments. However, all experimental diets resulted in better growth of yellow perch than the commercial salmonid starter.

An accompanying study using the same batch of fish, the same commercial diet, and three different experimental diets was conducted at the Piketon Research and Extension Center. Four groups per treatment were used and a semi-purified, casein-gelatin diet (#l) was tested along with diets based on krill and squid meals (#2) or fish meals (#3). In a trial in Piketon, four weeks of feeding resulted in significantly lower growth rate of perch fed a semi-purfied diet (gain 70±8%) than both experimental diets (105±11 - 115±15%) or a commercial diet (104±7%).

OBJECTIVE 2

An experiment was conducted by University of Wisconsin-Madison (UW-Madison) researchers at Coolwater Farms, LLC, to determine key parameters for producing yellow perch fingerlings habituated to formulated feeds and reared in ponds for an entire growing season, and to compare the performance of two types of pond lighting and feeding systems. Ponds are currently being harvested and production data are being collected. Observations made by Coolwater Farms culturists indicate that improvements in pond lighting and feeder design markedly reduced the labor needed for husbandry and system maintenance.

In the late spring and early summer of 1996, University of Nebraska-Lincoln (UNL) investigators compared the utility of different lighting systems, combined with a specially designed trap-net, to harvest photopositive young-of-the-year (YOY) yellow perch on a large scale from ponds. Previous research using similar capture gear had demonstrated that up to 38,000 young yellow perch could be captured per 30-min effort from heavily stocked, shallow (<1.25-m; 4.1-ft) earthen ponds of 0.4 ha (1 acre) surface area or less.

The 1996 trials compared the utility of different configurations of lights arrayed on rafts that could be easily pulled from an opposing pond shoreline to the trap-net. Trials were conducted at the Calamus State Fish Hatchery (near Burwell, Nebraska), in two plastic-lined 0.2-ha (0.5-acre) ponds that when full have an average depth of well over 1.25 m (4.1 ft). Both ponds were stocked with about 225,000 yellow perch fry, and managed by standard procedures used by the Nebraska Game and Parks Commission. Harvesting trials were initiated when the fish in each pond reached 19 mm (0.7 in) total length.

Two light-raft systems were tested. The lights on both could be turned on or off by remote control. One raft was equipped to broadcast a total of 250 W of omnidirectional light below water. The second was equipped to broadcast a total of 910 W of omnidirectional-submerged, directional-submerged, and directional above-surface lighting. The directional lighting on the latter system was broadcast forward of the raft as it was pulled through the water.

The trap-net was fitted with a string of five 75 W submerged lights that were turned off sequentially to draw fish into an open-top harvest pot, designed to facilitate the low-stress crowding and capture of small fish. The design of this trap-net has been proven effective at capturing large numbers of photo-positive young fish when used in combination with a variety of lighting systems in shallow earthen ponds.

The results of the 1996 UNL trials were that the 910 W light raft effected the capture of significantly greater numbers of yellow perch (about 5,000 fish per 30-min capture effort) than the 260 W light raft (about 3,800 fish per capture effort). The number of capture efforts made with each system were 14 and 17, respectively. One particularly noteworthy observation was that the numbers of yellow perch captured per unit effort in 1996 was significantly down from previous years (typically 10,000-20,000 fish per capture effort). This was attributed primarily to the fact that the Nebraska Game and Parks Commission added AquaShade® to the ponds to prevent excessive algae growth, and possibly to the greater depth of the ponds used in 1996. AquaShade® is a commercially available product that reduces light transmittance in water.

Extremely poor weather conditions, combined with budgetary shortfalls, precluded UNL testing of this or similar harvesting equipment at sites other than the Calamus State Fish Hatchery. Three years of research by UNL investigators on the use of light to harvest YOY yellow perch indicate that it is a very useful tool but can yield highly variable results, depending on a number of factors, e.g., pond depth and area, plankton concentrations, presence of aquatic vegetation, size and age of fish.

OBJECTIVE 3

During 1996, two "Intensive Aquaculture of Yellow Perch in Conjunction with Recirculating Aquaculture Systems" workshops were sponsored by the University of Wisconsin Sea Grant Institute, which included NCRAC Extension and Yellow Perch Work Group members. Alpine Farms (Sheboygan Falls, Wisconsin) personnel participated as aquaculture industry cooperators to provide their practical experience with, and knowledge of, yellow perch rearing in their recirculating aquaculture system (RAS) technology.

The program for the first workshop included a morning session with lecture presentations and an afternoon poster session during which small groups of attendees had the opportunity for direct contact with the presenters, having their specific questions answered and problems solved. In order to maximize personal contact with the presenters, the number of attendees at this workshop was limited to 75.

ln the weeks following this workshop, small groups of workshop attendees were given the opportunity for additional direct hands-on advisory service concerning the technology for intensive rearing of yellow perch. These on-site activities were conducted at the University of Wisconsin System Aquaculture Institute in Milwaukee, and at Alpine Farms where they observed demonstrations on the intensive aquaculture of yellow perch in conjunction with a RAS.

A second one day workshop on the intensive culture of yellow perch with RAS was held in June 1996. The agenda for this workshop included lecture presentations on RAS operation and technology, water quality management in RAS, relevant aspects of yellow perch biology under intensive rearing, and the economic and business aspects of yellow perch culture. The format of this workshop was designed to focus on the most important topics and maximize the interaction between workshop attendees and aquaculture experts during an extended question/answer session. Eighty-five people attended this workshop.

Kayes of UNL conducted a workshop in Nebraska, part of which covered methods of harvesting yellow perch in ponds. In addition, progress was made on producing a videotape on the small-scale processing of yellow perch, in cooperation with videographers at Kansas State University.

WORK PLANNED

OBJECTIVE 1

Preliminary studies were conducted at MSU to develop larval rearing tank designs similar to those that have been used successfully in raising larval walleye and mahi mahi. The initial design will be improved in 1996-97 and used in feed acceptance studies. Also in 1996-97, MSU researchers will use their findings from 1995-96 to select spawners from size classes that produce favorable hatchability and mouth size traits in their fry. The fry will be used for nutritional studies comparing live and formulated dry diets.

After completion of the methionine requirement at Purdue, the dietary choline requirement will be quantified, then the ability of betaine to supply part or all of the choline requirement will be determined. Work at OSU will continue to evaluate the use of pancreatic enzymes and a digestive tract neurohormone, bombesin, in the diets offered to young yellow perch.

OBJECTIVE 2

A second experiment on pond fingerling production will be conducted by UW-Madison researchers at Coolwater Farms, LLC. This experiment will evaluate strategies to maximize fingerling survival and crop uniformity in perch cultured throughout a growing season.

Nearly all the NCRAC funds allotted to UNL for research on Objective 2 were exhausted in 1996. In 1996-97, UNL investigators will evaluate and compare the data collected over the past three years on harvesting YOY fish using light in preparation for submitting the findings to a peer-reviewed journal for publication, and as part of a NCRAC project termination report.

OBJECTIVE 3
A workshop demonstrating key facets of fingerling production and grow-out is being planned by UW-Madison researchers for June 1997.

The “Intensive Aquaculture of Yellow Perch in Conjunction with RAS Technology" workshops presented by University of Wisconsin-Milwaukee in 1996 provided the framework for the presentation of a hands-on workshop to be organized and presented in 1997. They intend to install a demonstration RAS at the University of Wisconsin System Aquaculture Institute in Milwaukee that can be directly used for hands-on participation and training of workshop attendees.

A NCRAC-sponsored conference and two workshops on yellow perch aquaculture will be held in Nebraska in 1996-97. Also, the videotape on the small-scale processing of yellow perch, which was proposed by Kayes of UNL, should be completed.

IMPACTS

Defining critical nutritional requirements for targeted species reduces feed costs and overall cost of production. These data will be important pieces of information for manufacturers of feed. This research provides strong evidence that commercial diets for salmonids need to be modified to meet nutritional requirements of yellow perch. These new diet formulations may significantly improve growth rate of yellow perch fry. Further, definite use of legal flavor additives may alleviate the problems of poor feed acceptance by larval and growout perch.

Studies on pond fingerling production by UW-Madison researchers have shown that research based production strategies can be used on a commercial scale to produce large numbers of yellow perch fingerlings at a relatively low cost. Lights and automatic feeders used to habituate fingerlings to formulated feeds while they remain in ponds can be used throughout the first growing season, eliminating the need for a separate feed-training phase of production. Improvements in feeder design may increase reliability and decrease capital and operational costs.

The field trials conducted by UNL investigators have demonstrated both the utility and the limitations of using light to harvest YOY yellow perch. Present indications are that light is being used by increasing numbers of fish farmers to harvest young yellow perch (as well as other species) in several states including Ohio, Minnesota, and Wisconsin.

Workshops done on yellow perch aquaculture in the NCR have stimulated increased interest in this species among established fish farmers, potential fish farmers, and the general public. In the past year, requests for information on yellow perch aquaculture have increased significantly; for example, requests for yellow perch culture information from Kayes at UNL have increased by about 500%.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix A.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1993-94	$75,000	$87,240	$30,000	$10,000[a]		$127,240	$202,240
1994-95	$75,000	$81,587	$30,000	$81,000[abc]		$192,587	$267,587
1995-96	$107,086	$145,814	$20,000	$134,000[ac]		$299,814	$406,900
TOTAL	$257,086	$314,641	$80,000	$225,000		$619,641	$876,727

[a]Sea Grant/USDC/NOAA
[b]USDI, Bureau of Indian Affairs
[c]EPA

HYBRID STRIPED BASS

Project Component Termination Report for the Period
September 1, 1993 to August 31, 1996

NCRAC FUNDING LEVEL: $258,270 (September 1, 1993 to August 31, 1996)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
George G. Brown	Iowa State University	Iowa
Paul B. Brown	Purdue University	Indiana
Konrad Dabrowski	Ohio State University	Ohio
James E. Ebeling	Ohio State University	Ohio
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
Jeffrey A. Malison	University of Wisconsin	Wisconsin
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Bruce L. Tetzlaff	Southern Illinois University-Carbondale	Illinois
M. Randall White	Purdue University	Indiana
Extension Liaison:		
Joseph E. Morris	Iowa State University	Iowa

REASON FOR TERMINATION

The objectives of this project were completed.

PROJECT OBJECTIVES

(1) Develop larval diets and economically feasible techniques to convert hybrid striped bass young from zooplankton to prepared diets.

(2) Develop intensive hatchery production techniques for white bass and to "domesticate" white bass by producing brood stock originating from induced spawns.

(3) Improve methods for storage and transport of striped bass and white bass gametes.

PRINCIPAL ACCOMPLISHMENTS

In a comparative study conducted at Southern Illinois University-Carbondale (SIUC), hatching rates for embryos incubated in Heath trays (28.2%) were equivalent to tannic acid-treated (150 mg/L water) embryos incubated in Heath trays (22.9%) or McDonald jars (22.4%).

Facilities to intensively rear larval white bass were established at Ohio State University (OSU), SIUC, and the University of Wisconsin-Milwaukee (UW-Milwaukee). White bass larvae from three separate spawning trials were shipped by overnight freight to OSU and UW-Milwaukee. Attempts to rear larval white bass were minimally successful. Less than 1% survival rates were obtained by day 122 at UW-Milwaukee, day 45 at OSU, and day 24 at SIUC.

A group of white bass sac-fry shipped from SIUC to UW-Milwaukee was introduced evenly by volume into twelve 60-L (15.9-gal) flow-through aquaria. Each aquarium contained approximately 300 sac-fry. These fish were offered "green tank" water and the three experimental diets that were provided by Purdue University (Purdue). The length of the cylindrical food particles ranged from approximately 0.5 to 1.7 mm (0.02 to 0.07 in) and the diameter was 420-595 µm. White bass sac-fry are approximately 3.5 mm (0.14 in) in total length. The cross sectional diameter of the feed approximated the width of the entire head (550-630 µm) of white bass sac-fry, and was outside of the range of the width of the mouth. UW-Milwaukee researchers ground portions of the diets in a mortar and pestle and sieved it through a 150 µm mesh to obtain more suitable-size particles. From May 26-31, 1995, each of the three ground and sieved diets was offered to fry in triplicate aquaria along with "green tank" water. The controls received only "green tank" water. No feeding activity or interest by the fry in the formulated diets was observed. Mortality of the sac fry was heavy in all the tanks and by May 31 (within 6 days), less than a dozen fry were observed in any of the aquaria and more than half of them had only one or no living fry. At this point the trial was terminated.

Researchers at SIUC found that both hybrid striped bass crosses at a 2-5 g (0.07-0.18 oz) size range readily convert from zooplankton to formulated feed. Over 90% of the fish converted to formulated feed within two days as compared to 70-85% after seven days for largemouth bass which were trained in a "side-by-side" study. Preliminary results indicate that white bass and reciprocal-cross hybrids are equivalent in this regard and can make the switch between day 21 and 28 after hatch. Original cross hybrids can generally be switched at day 7 after hatch.

A problem facing hybrid striped bass aquaculturists is that hybrid fry are not always available. Gametes must be obtained from two species that may not be spawning simultaneously or are located in different geographical areas. Therefore to facilitate hybrid production, viable *Morone* semina need to be readily available when ripe eggs are available.

To aid in the solution of this problem, procedures for reliable short-term (refrigerated) and long-term (cryopreservation) storage of striped bass (*Morone saxatilis)* semina were developed. Initially, the characteristics of high quality spermatozoa were examined to determine methods for assessing sperm quality and developing effective sperm handling techniques. This led to the formulation of extenders for short-term (less than 21 days) refrigerated (1°C; 33.8°F) storage. The quality of stored seminal samples was tested by determining sperm motility percentages and developing a sperm quality index (SQI). Refrigerated extended seminal samples were routinely stored for 14 days with 50% sperm motility.

Cryopreservation procedures were developed and sperm quality of cryopreserved seminal samples of striped bass were assessed. Fertility tests with these samples were performed with white bass (*M. chrysops*) eggs and results were compared to those results when using (fresh) white bass semen.

Ten media containing dimethylsulfoxide (DMSO) were used to cryopreserve striped bass spermatozoa. Although all media successfully cryopreserved spermatozoa, the best motility (SQI 2.3: about 50%) was obtained with samples cryopreserved in the five media containing 4% DMSO. Using the criteria for high quality semen, the samples cryopreserved in media containing 4% DMSO with or without trehalose and bovine serum albumin gave the best motility results and were used in fertility tests with white bass eggs. Straws of the cryopreserved samples were transported from Florida to SIUC packed in dry ice. These were then stored in liquid nitrogen until used in fertility tests. Striped bass spermatozoa were cryopreserved with relatively simple methods. This may partially be because of the small size of the sperm, causing damage by the freezing process to be minimal since the cryogenic medium penetrates the whole cell very rapidly and the actual freezing may be rapid enough to prevent damaging ice crystal formation.

In the hybrid cross, the study was pursued until the hatch of normal larvae. Although success with cryopreserved spermatozoa has previously been reported for striped bass results were determined on the basis of cleavage, which does not necessarily indicate the normal development of diploid embryos. Fertility was tested using striped bass semen cryopreserved in cryogenic media and white bass eggs. The percent fertilization based on the number of hatched, normal larvae was 6.2 % for the cryopreserved semen and 2.5% for the eggs fertilized with fresh control white bass semen (dead and abnormal larvae were excluded). This represented a 251.2% hatch from cryopreserved semen related to control semen. No development was found in control eggs (unfertilized eggs) tested for parthenogenesis.

The motility intensity of thawed and activated cryopreserved spermatozoa was roughly equivalent to that of seminal samples activated after 14-21 days of refrigerated storage, indicating that cryopreservation of striped bass semen may be the best option when storage time exceeds 21 days.

Emphasis was also focused on developing refrigerated and frozen storage methods for white bass spermatozoa. Evaluations of sperm motility and nuclear magnetic resonance (NMR) were used as measures of success in developing methodologies. NMR was used to measure the availability of high energy phosphorus compounds to power flagellar movements in spermatozoa.

Sperm quality was best when seminal samples were extended prior to shipping and when they were transported in tissue-culture flasks which provided a larger air space than the microcentrifuge tubes which were also tested as shipping containers. Extenders with simple formulations, including one that was essentially only a saline solution, were as good or better than a more complex extender solution for maintaining sperm quality during refrigerated storage at 1°C (33.8°F). The simple saline solution extender maintained good sperm quality for up to one month of refrigerated storage.

Declines in high-energy phosphorus compounds and increases in their breakdown product, as measured via NMR, corresponded with declines in sperm motility over time during refrigerated storage of semen. However, NMR detected differences in stored energy in spermatozoa among seminal samples when no such differences in sperm motility were detected, indicating that NMR may be a more sensitive measure of sperm quality.

It was found that a cryogenic solution consisting of a simple extender and DMSO as the cryoprotectant performed as well as more complex cryogenic media in sperm motility tests. Fertility was somewhat reduced using cryopreserved semen, as compared to semen which had been extended and stored at 1°C (33.8°F) for about one week. Cryopreservation reduced white bass sperm motility to 5 to 25% of motility in fresh semen samples, a reduction similar to that found in seminal samples which are extended and stored under refrigeration for about four weeks. It is recommended that refrigerated storage be used for white bass semen if storage times of one month or less are anticipated. Cryopreservation is the better option, if sperm storage is to exceed one month.

IMPACTS

Studies by the Hybrid Striped Bass Work Group demonstrate that:

- Improvements in hatching rates allows for increased hatchery production or reduction in brood stock needs.
- Improvements in larval rearing techniques of white bass will allow "true" domestication.
- Improvements in switching hybrid striped bass fingerlings from zooplankton to formulated feeds will increase production efficiency.
- *Morone* semen which is to be stored should be kept cold at all times subsequent to stripping.
- White bass injected with hCG once per month and held at 15°C (59.0°F) produced 2 to 3 times as many spermatozoa as compared to those either given hCG once per week or no hCG but otherwise treated similarly--using this approach allowed semen to be obtained from each fish once per week for several months.
- Semen should be diluted with an extender prior to shipping and transported on ice.
- Relatively simple extender solutions (saline solutions) are effective for refrigerated storage of *Morone* semen.
- Tissue culture flasks proved to be better than microcentrifuge tubes for shipping white bass semen--this difference was attributed to the oxygen in the larger air space of the former.
- *Morone* semen can be extended and stored at 1°C (33.8°F) and good motility can be retained for 3 to 4 weeks.
- Initial evaluations indicated that changes in NMR spectra of seminal samples are consistent with changes in sperm motility; however, NMR may provide a more sensitive measure of semen quality.
- Cryopreservation reduced sperm motility by about 50%, as compared to extended semen.
- A relatively simple cryogenic medium (4% DMSO in a simple extender solution) was effective for storing *Morone* semen.
- Excellent fertility in white bass eggs was obtained using cryopreserved striped bass semen, and good fertility was obtained using cryopreserved white bass semen.
- Based on reductions in sperm motility, cryopreservation is the better option for *Morone* semen if it is to be stored for more than 3 to 4 weeks, whereas refrigerated storage is better for shorter storage times.

RECOMMENDED FOLLOW-UP ACTIVITIES

The North Central Regional Aquaculture Center is currently funding studies aimed at comparing different geographical strains of hybrid striped bass and white bass in ponds. These studies are incorporating spawning, sperm storage, and hatchery procedures developed in this project. The sperm storage protocols are also being tested in industry settings. Collectively, the results from past and current studies should pave the way to economically undertake hybrid striped bass culture in the North Central Region. Continued demonstration of the technologies developed need to be undertaken with industry partners.

SUPPORT:

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1993-94	$81,000	$58,679				$58,679	$139,679
1994-95	$87,000	$60,671				$60,671	$147,671
1995-96	$90,720	$85,117	$55,019			$140,136	$230,856
TOTAL	$258,720	$204,467	$55,019			$259,486	$518,206

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix A.

HYBRID STRIPED BASS

Progress Report for the Period
September 1, 1995 to August 31, 1996

NCRAC FUNDING LEVEL: $90,270 (September 1, 1995 to August 31, 1996)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Michael L. Brown	South Dakota State University	South Dakota
Paul B. Brown	Purdue University	Indiana
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
Jeffrey A. Malison	University of Wisconsin	Wisconsin
Joseph E. Morris	Iowa State University	Iowa
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Extension Liaison:		
Joseph E. Morris	Iowa State University	Iowa
Non-Funded Collaborators:		
Robert Lyons	Lyons Enterprises, Morocco	Indiana
Gary Shirley	Shirley's Fish Farm, Lafayette	Indiana
Mike Freeze	Keo Fish Farm, Inc., Keo	Arkansas
Scott Lindell	AquaFuture, Turners Fall	Massachusetts

PROJECT OBJECTIVES

(1) Examine fry (phase I) to fingerling (phase II) production of three strains of white bass and three strains of hybrid striped bass (sunshine bass) in ponds with and without lights and vibrating feeders.

(2) Conduct field testing of fingerling (phase II) to advanced fingerling (phase III) production of three strains of hybrid striped bass (sunshine bass) in various culture systems.

(3) Extension component:

(a) Coordinate selection of various culture systems and implement field testing (fingerling to advanced fingerling to food size).

(b) Write an initial culture manual using the information generated by all the hybrid striped bass research sponsored by the North Central Regional Aquaculture Center.

(c) Produce associated fact sheets, bulletins, and videos for hybrid striped bass research in the North Central Region.

ANTICIPATED BENEFITS

The overall goal of this collaborative project is to enhance hybrid striped bass aquaculture in the North Central Region (NCR). Hybrid striped bass are consistently identified as a high priority species within the NCR and consistently ranked as a preferred species to eat (unpublished data from Purdue University). Out-of-season spawning of white bass has been achieved in an ongoing North Central Regional Aquaculture Center (NCRAC)-sponsored project. The development of intensive larval culture techniques for this species will allow for its full domestication. The development of techniques for semen storage (cryopreservation and extended) preclude the need for maintaining large numbers of male striped bass brood stock. The logical next step is to conduct field trials of several strains of white bass and hybrid striped bass in various culture systems. Existing producers need to improve the economics of hybrid striped bass production by increasing stocking densities and improving feeds. The break-even production cost of hybrids grown in cages is reported o be $2.29 to $3.45/kg ($1.04 to $1.56/lb). Those values were based on a stocking density of 100/m^3 (2.8/ft^3) and feed costs of $0.55/kg ($0.25/lb). As production of hybrids increases on a regional and national scale, market price will likely decrease. Thus, this research will help maintain current profit margins as production increases. The knowledge gained from this study should be of immediate use by the aquaculture industry. The extension component of the study will assure that research information gets to the industry in a user-friendly form. Although the proposed project is not directly interregional with respect to physical performance, lines of communications have, and will continue to be maintained with the Hybrid Striped Bass Grower’s Association and other researchers, specifically: Harrell, Woods, and Zohar at the University of Maryland; Smith and Jenkins at the South Carolina Department of Natural Resources; and Hodson and Sullivan at North Carolina State University.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVES 1 AND 2

<u>Southern Illinois University-Carbondale (SIUC)</u>

Brood Stock Acquisition: Adult white bass were acquired by SIUC researchers from three regions representing the extremes of white bass' native range: Arkansas, South Dakota, and Lake Erie. Arkansas white bass were collected by trap netting in the Arkansas River. The South Dakota stock of white bass was collected by South Dakota State University (SDSU) by angling in Lake Kampeska, South Dakota. Lake Erie white bass were collected by commercial fishermen in Sandusky Bay of Lake Erie. Brood fish were held at SIUC in recirculating systems in winter conditions (8°C [46.4°F] and 10 hours daylight) until all three stocks of fish were collected.

Spawning of Brood Stock and Incubation of Larvae: Once all three stocks of fish were acquired, temperature and number of daylight hours were gradually increased until 16°C (60.8°F) and 14 hours, respectively, were reached. During this warm-up phase brood fish were fed minnows on a daily basis. When spawning temperature and number of daylight hours were obtained, female white bass were injected with hCG at a rate of 150 IU/kg (68.4 IU/lb) to induce ovulation. Males were injected at a rate of 100 IU/kg (45.5 IU/kg) to enhance semen production. Extended striped bass semen was obtained from Keo Fish Farm, Arkansas, so that sunshine bass could be produced.

At least ten females of each stock ovulated, at which point the eggs were manually stripped and divided into two allotments. One allotment of the eggs was fertilized with white bass neat semen to produce pure white bass, while the other allotment of eggs was fertilized with extended striped bass semen to produce sunshine bass. Both allotments of eggs were treated with tannic acid to reduce the adhesiveness of the eggs. Eggs were then incubated in MacDonald jars until hatch. Hatch was complete at about 48 hours postfertilization.

Enumeration and Stocking of Larvae: At four days of age, the larvae were enumerated and subsequently stocked into ponds. In order to enumerate the larvae, ten samples of 100 mL (3.4 oz) were randomly drawn from each holding tank. The number of larvae in each sample was counted. From the ten samples an average number of larvae per volume was calculated. This average value was used to extrapolate to the total volume of the holding tank. This procedure was repeated for all six stocks of fish.

Ponds used in this study are approximately 0.04 ha (0.10 acres); however, each pond's length and width were measured to determine its individual surface area. Larvae were transported from the holding tanks to the Touch of Nature pond facility in bags containing approximately one-third fish and water and two-thirds pure oxygen. Stocking of larvae began at dusk and continued after dark. Larvae were stocked at a rate of 500,000/ha (202,350/acre). Each stock of fish was stocked in quadruplicate.

Pond Filling and Fertilization: Ponds were filled 5-10 days prior to stocking and incoming water was filtered using a nylon "sock" with a mesh size of 500 µm. Ponds were fertilized using both cottonseed meal and 8-32-16 inorganic fertilizer. A single application of cottonseed meal was administered at 350 kg/ha (312.3 lb/acre) 4-5 days prior to stocking. The inorganic fertilizer was applied at 25 kg/ha (22.3 lb/acre) twice weekly for five weeks. An additional application of cottonseed meal was administered once weekly at 25 kg/ha 22.3 lb/acre) starting in week 4.

Feeding of Phase I Fingerlings: Training the fish to accept prepared feed began 21 days poststocking. Fish were offered frymeal twice a day at 5-10 kg/ha/day (4.5-8.9 lb/acre/day). Once fish were observed accepting prepared feed, pellet size was increased as necessary and fish were fed to satiation. Feed amounts were recorded twice daily.

Harvesting Phase I Fingerlings: At 36-41 days of age phase I fingerlings were harvested by seining. Survival rate varied from pond to pond, but was generally poor. The highest survival rate for any pond was 21.3%, while the lowest survival rate was 0.0%. Survival rates were markedly higher for hybrid striped bass ponds versus white bass ponds averaging 12.8% and 2.6%, respectively. Average weight of an individual fish in any particular pond was inversely related to its survival rate; that is, if a pond had a high survival rate, then the average weight of an individual within that pond tended to be low. This trend is reflected in the relatively low average weights of hybrid striped bass (1.5 g; 0.05 oz) and the relatively high average weights of white bass (2.2 g; 0.08 oz). Average weights were calculated by weighing 120 individuals from each pond.

Phase II Production: Phase I fingerlings which were harvested were restocked for phase II production. Due to a lack of fish, all three white bass stocks were eliminated from this segment of the experiment. Both Arkansas and South Dakota hybrid striped bass stocks were restocked in triplicate, while Lake Erie hybrid striped bass were only restocked in duplicate. The stocking rate used for phase II production was 25,000 fish/ha (10,117.5/acre). Fish were offered feed two times per day. Fish were fed to satiation and feed amounts were recorded twice daily. One grass carp was stocked per pond to serve as a control on aquatic vegetation.

Harvesting Phase II Fingerlings: At the end of the growing season, phase II fingerlings were harvested by seining. Survival rates ranged from a low of 49.2% to a high of 85.8%. Survival rates for both Arkansas and Lake Erie hybrid striped bass were about 72%, while the survival rate for South Dakota hybrid striped bass was only 56.6%. The average weight of individual fish also varied from stock to stock. The highest average weight was 90.2 g (3.2 oz) for Lake Erie hybrid striped bass, while South Dakota and Arkansas hybrid striped bass had average weights of 69.0 g (2.4 oz) and 58.4 g (2.1 oz), respectively. Average weights were calculated by weighing 50 individuals from each pond.

South Dakota State University (SDSU)

Two groups of hybrid striped bass fingerlings were transported from SIUC to SDSU to conduct strain comparison and density experiments. The two groups of offspring were produced either with female white bass collected from the Arkansas River, Arkansas, or Lake Kampeska, South Dakota, and stored striped bass spermatozoa maintained at SIUC, originating from Keo Fish Farm, Arkansas. These experiments, which began on August 16, 1996, will continue for approximately another 110 days.

The culture system for both experiments consists of 110-L (29.1-gal) glass aquaria connected as a closed freshwater recirculating system with a delivery rate of approximately 1 L/min (0.26 gal/min). Ammonia, nitrite, nitrate, pH, hardness, alkalinity, and carbon dioxide are measured every two days. Water temperature is maintained at 22°C (71.6°F) and dissolved oxygen is maintained near saturation by continuous aeration; both are monitored several times weekly. A light/dark cycle of 12-h light/12-h dark is maintained using incandescent lighting controlled by an automatic electric timer.

Initial mean weights were 3.6 g (0.13 oz) and 2.9 g (0.10 oz) for Arkansas and South Dakota hybrids, respectively. The diet (38% protein, 8% crude fat) used in both experiments was obtained from Southern States Cooperative, Inc. (Richmond, Virginia). All fish were conditioned for a 2-week period by feeding a #4 crumble *ad libitum* two times per day. Randomly selected fish from each strain group were then stocked in individual aquaria to provide four replicates. The feed was supplied to fish initially at a rate of 10% of body weight per day equally divided into four feeding periods. All feeding is done with belt feeders. The feeding rate will be progressively reduced to 3% of body weight during the experiment to minimize overfeeding while maintaining a level approaching satiation. Also, pellet sizes fed are periodically increased with graded changes in body size. Waste material is siphoned from each aquaria every other day. Group and individual measurements are made at weekly intervals. Feed allotments are adjusted weekly. The same general protocol is being applied to the density experiment. Four replicates each of 5 ($45/m^3$; $1.3/ft^3$), 15 ($136/m^3$; $3.9/ft^3$) or 30 ($273/m^3$; $7.7/ft^3$) South Dakota hybrids per 110-L (29.1-gal) aquaria are being maintained at present. Performance characteristics (e.g., growth, conversion, condition, survival) are monitored in both experiments.

Purdue University (Purdue)

In the first year of the Purdue project, a private producer was going to provide fingerlings for the first evaluation, but none of the fish survived overwinter at the producer's site. A secondary supplier was identified and fish were brought to Indiana. However, most of those fish died due to the stress of a 15 hour haul. Cages were stocked at both field sites and will be harvested in November 1996. The tank loading study was initiated in late-summer 1996 and will be completed by December 1996. In a series of studies, soy products have been evaluated as a replacement for fish meal in diets. Maximum incorporation of raw soybeans was less than 20%, while roasted soybeans could be incorporated up to 20%. Solvent-extracted soybean meal could be incorporated up to 40% of the diet if sufficient mineral supplementation was provided.

OBJECTIVE 3

Iowa State University and SIUC

Kohler and Morris served as co-chairs for the NCRAC Hybrid Striped Bass Workshop that was held in November 1995 in Champaign, Illinois. The topics for the workshop included larval culture, cage culture, brood stock management, and an industry perspective; the 35 attendees were from Illinois, Iowa, Indiana, and Missouri. NCRAC-funded speakers included Chris Kohler, Sue Kohler, and Bob Sheehan (SIUC), George Brown and Joe Morris (Iowa State University) and LaDon Swann (Purdue). A hybrid striped bass fact sheet developed by Morris and Kohler is in press.

WORK PLANNED

OBJECTIVES 1 AND 2

SIUC

Phase II fingerlings were redistributed at a rate of 4,940 fish/ha (2,000/acre) for phase III growout. There are five replicates for each stock of hybrid striped bass. Feeding will resume as early in spring 1997 as possible and will occur twice a day until the end of the 1997 growing season.

Studies in aquaria are being conducted to compare the three strains of hybrid striped bass and the three strains of white bass. This study is being conducted as a "control" for the pond studies.

University of Wisconsin-Madison and University of Nebraska-Lincoln

Pond studies comparing survival of larval hybrid striped bass and white bass with and without lights and vibrating feeders will be carried out in 1997.

SDSU

During the summer of 1997, plans are to evaluate performance characteristics of three strains of hybrid striped bass (Arkansas, South Dakota, and Lake Erie female white bass sources) under flowthrough conditions. Phase II fish, supplied by SIUC, will be transported to SDSU and stocked in an indoor flow-through system comprised of 1,100-L (290.6-gal) rectangular tanks. Each strain will be stocked into a minimum of three replicate flow-through tanks at similar densities.

Commercial feed will be dispensed by belt feeders. General environmental conditions will be similar to those maintained during fall 1996. Trials will continue until each strain reaches a marketable size. Dressed and fillet proportions, and composition will be determined following harvest.

Purdue
Fish for the second year of the project have been acquired and will be reared at the Purdue University Aquaculture Research Facility. Thus, problems in acquisition and transport have been eliminated. Two commercial aquaculture facilities (Lyons Enterprises and Shirley's Fish Farm) will be stocked in April 1997 and fish grown until November of 1997. Stocking densities will be 100, 150, and 200 fish/m^3 (2.8, 4.2, and 5.7 fish/ft^3). Tank stocking densities will range from 50 to 300 fish/m^3 (1.4 to 8.5 fish/ft^3), with flow rates held constant at 1.0 L/min (0.26 gal/min).

OBJECTIVE 3
The culture manual will be written in 1997. One or more videos will also be developed.

IMPACTS
Much of the technology developed over the course of NCRAC-sponsored hybrid striped bass research was incorporated in the current project. For example, wild white bass brood stock were obtained from three distinct geographic locations and transported to SIUC where they were habituated to captivity and induced to spawn using hormones. Stored striped bass semen obtained from Keo Fish Farms, Arkansas, was then used to produce hybrid striped bass. Eggs were incubated using the jar technique and fry were stocked into newly fertilized ponds. Fingerlings were switched to formulated feed in the ponds and phase II production was carried out. Feed-trained fingerlings were also sent to SDSU for additional studies in aquaria and raceways. Identification of the maximum density of fish in cages and tanks will allow maximum use of production space and resources; thus, increasing profitability of culture. Use of soybean products in diets decreases the cost of feed, while not sacrificing weight gain or health of fish. Further, these new formulations can be manufactured in the NCR. These studies, taken collectively, will not only meet the stated objectives of the project, but also will serve as a demonstration of the bulk of the technology developed by the NCRAC Hybrid Striped Bass Work Group since its inception.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED
See Appendix A.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1995-96	$90,270	$85,117	$55,019			$140,136	$230,406
TOTAL	$90,270	$85,117				$140,136	$230,406

WALLEYE

Progress Report for the Period
September 1, 1995 to August 31, 1996

NCRAC FUNDING LEVEL: $117,897 (September 1, 1995 to August 31, 1996)

PARTICIPANTS:

Jeffrey L. Gunderson	University of Minnesota	Minnesota
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Ronald E. Kinnunen	Michigan State University	Michigan
Jay A. Leitch	North Dakota State University	North Dakota
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Marshall A. Martin	Purdue University	Indiana
Patrick D. O'Rourke	Illinois State University	Illinois
Jean R. Riepe	Purdue University	Purdue
Robert C. Summerfelt	Iowa State University	Iowa
David H. Wahl	Illinois Natural History Survey	Illinois
Extension Liaison:		
Ronald E. Kinnunen	Michigan State University	Michigan
Non-funded Collaborators:		
Larry Belusz and Greg Raisanen	Alexandria Technical College	Minnesota
Nebraska Game & Parks Commission	Calamus State Fish Hatchery, Burwell	Nebraska

PROJECT OBJECTIVES

(1) Evaluate growth, feed efficiency, and stress responses as functions of density, loading, temperature, and feeding regimes (feeding rate and frequency) under tank and open-pond rearing conditions for raising juvenile walleye to food size.

(2) Characterize the economics and institutional aspects of the domestic market for walleye as food fish, fingerlings, and other intermediate products.

(3) Offer several workshops in the North Central Region, using extension materials (fact sheets, videos, etc.) and other information that has or will be developed necessary to demonstrate the technology of culturing walleye and its hybrids.

(4) Complete performance evaluations of walleye × sauger hybrids to finalize research initiated during the 2-year project period of the June 1993 proposal - including studies on fillet yield, proximate analysis, and organoleptic properties.

ANTICIPATED BENEFITS

This project is addressing priority needs identified by the North Central Regional Aquaculture Center (NCRAC) Industry Advisory Council (IAC), as well as specific objectives adopted by the NCRAC Board of

Directors, to advance the development of commercial walleye aquaculture in the North Central Region (NCR). Two major lines of research are being pursued: first, to determine whether this species can be cultured to food size under practical conditions, at rearing densities and in a time frame conducive to commercialization; and second, to evaluate the nature and scope of the domestic market for walleye.

In addition, research is being completed to determine if one or more combinations of walleye and sauger genetic stocks can be used to produce hybrids that exhibit superior growth and performance characteristics, compared to purebred walleye. Collectively the data generated by research on both purebred and hybrid walleye will provide critical information to facilitate economic analyses of production costs, and provide extension professionals and private fish producers with new knowledge and training materials on key aspects of walleye aquaculture.

The research being done as part of this project on the production of walleye to food size is (1) evaluating survival, growth, feed efficiency, and stress responses under various culture conditions; (2) examining methods of estimating growth and feeding rates under conditions that span the optimum temperature range for juveniles, with the goal of developing feeding tables for walleye; (3) adapting a bioenergetics model for use in projecting walleye growth and making feeding recommendations under various culture conditions; and (4) completing studies comparing the growth, performance, and other characteristics of walleye hybrids and purebreds up to food size.

The research being done to investigate the domestic walleye market is documenting critical information about the historic and potential imports of Canadian walleye, and the potential negative price impacts such imports could have on a fledgling domestic walleye aquaculture industry. A clearer understanding of wild-caught supplies, market pricing systems, marketing channels, and institutional structures will assist walleye producers to position themselves better to achieve profitability; help plan production, financing and marketing strategies; and provide insights on the potential effect farm-raised walleye products will have on the domestic market for this species.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Research in Year 1 of the project on this objective was conducted by investigators from Iowa State University (ISU), the Illinois Natural History Survey (ILNHS), University Nebraska-Lincoln (UNL) and the University of Wisconsin-Madison (UW-Madison). Much of the work done was preparatory to definitive research that will be completed in Year 2.

Studies by ISU investigators were done using walleye hatched and raised to fingerling size at ISU in 1995. Final weight, percentage weight gain, and specific growth rate (percent weight gain per day) was greater for walleye cultured at 25°C (77.0°F) than at 20°C (68.0°F), but the difference was not statistically significant ($P > 0.05$). At 25°C (77.0°F), growth (total percentage weight gain) and specific growth rate in fish of 250-300 mm (9.8-11.8 in) total length (TL), at feeding rates of 1.5 and 2.0 (percent body weight per day) were not significantly different.

Work by ILNHS investigators has thus far focused on modifying an existing bioenergetics model for walleye using more recently developed metabolic parameters and better measures of specific inputs. Determinations of caloric levels contained in individual whole walleye and formulated feeds (by Parr adiabatic bomb calorimetry) and feces (by microbomb calorimetry) are nearing completion. Preparations have been made to enter data into the model from tank experiments using water temperature and food consumption as input variables.

The main focus of UNL investigators in Year 1 of the project was to raise a large number of Age-0 juvenile walleye for use in Year 2 production trials aimed at culturing fish to market size under practical conditions. On June 6, 1996, UNL researchers harvested about 43,200 walleye of 28.5 mm (1.1 in) mean TL and 0.7 g (0.02 oz) mean body weight from 0.4-ha (1.0-acre) production ponds at the Calamus State Fish Hatchery near Burwell, Nebraska. Equal numbers of these fish (about 2,700) were assigned to 16 840-L (222-gal) cylindrical tanks, enclosed in a darkened Aquashelter® (Tuttle Industries, Friend, Nebraska).

All 16 tanks were equipped with in-tank lighting and 24-hour belt feeders (Zeigler Bros., Gardners, Pennsylvania), and supplied with Calamus Reservoir water run through packed columns for aeration. A feeding trial was conducted comparing a diet developed for juvenile walleye by Rick Barrows of the U.S. Fish and Wildlife Service (Bozeman, Montana) and "Silver Cup" salmon starter-series diet (Murrey Elevators, Murrey, Utah). Far more walleye were habituated to the Barrow's diet than the Silver Cup diet. However, overall survival from the beginning to the end of the trial was extremely poor. On July 12, 1996, less than 3,000 of the original 43,200 walleye remained alive, despite every effort to maximize survival. This poor survival was attributed primarily to facilities problems, though cannibalism was also a contributing factor. Significant disease problems were not observed. By October 9, 1996, only 973 walleye remained alive, though they were healthy and in excellent condition. Their mean total lengths and body weights were 161 mm (6.3 in) and 33.3 g (1.17 oz), respectively. On that date, the remaining walleye were placed in tanks supplied with 13.3°C (55.9°F) well water for overwintering.

Investigators at UW-Madison conducted experiments to measure changes in blood serum concentrations of cortisol, glucose, and chloride, following acute stress challenge tests of walleye acclimated to different water temperatures. Preliminary findings suggest that the stress-induced cortisol rise in walleye is far quicker and returns to baseline values faster than in rainbow trout, but peak values in the two species are comparable. After being stressed, walleye held at 15°C (59.0°F) had lower peak cortisol levels, which took longer to return to baseline levels, than walleye held at 21°C (69.8°F). Holding walleye above their thermal optimum (25°C; 77.0°F) prior to being stressed accelerated the initial cortisol rise to peak levels and delayed the return to baseline - suggesting a stronger, more prolonged stress response.

OBJECTIVE 2

Investigators at Illinois State University completed a walleye market survey and an in-depth walleye fingerling culture and fish market literature review. The primary focus of the literature review was to identify any past research that might prove useful in describing the market for walleye fingerlings. Little of use was found. Information on the fingerling markets in Canada, the U.S. and the NCR was collected from research and extension experts, and from public and private suppliers and producers of walleye fingerlings using telephone interviews and mailed survey instruments.

Purdue University researchers conducted an in-depth literature review, which included the trade literature for food wholesalers, supermarkets, and restaurants; and developed a mailing list for those types of firms for the 12 states in the NCR. Supermarket and restaurant surveys were initiated in two phases. Phase 1 surveys differed for restaurants and supermarkets, and were limited to asking for general information on purchases and sales of fishery products. These surveys identified those restaurants and supermarkets where walleye was sold in 1996. The initial mailing was completed in the last week of August and the first week of September 1996.

North Dakota State University (NDSU) investigators have recently begun to collect published and secondary data on walleye exports from Canada to the U.S. This work got underway in August 1996.

OBJECTIVE 3

Two NCRAC-sponsored workshops on walleye aquaculture were held in 1996. The first, "Intensive Culture of Walleye: From Fry to Fingerlings on Formulated Feed," was held on May 7, 1996, at the Max McGraw Wildlife Foundation, Dundee, Illinois. Robert Summerfelt and Richard Clayton of ISU were the principal speakers, and Tom Harder of the McGraw Foundation provided a tour and detailed description of the McGraw fry culture facilities. The workshop covered nearly all aspects of walleye fry culture - including design of a large-scale culture system, fish husbandry techniques, and feeding. Terry Kayes of UNL videotaped the workshop with the assistance of Ron Kinnunen of Michigan State University. Nineteen people attended the workshop: five from Illinois, three from Iowa, two from Minnesota, four from Michigan, one from Nebraska, and four from Pennsylvania.

The second NCRAC workshop, "Production of Advanced Fingerling Walleye: Growth of Minnows in Ponds and Intensive Culture of Formulated Feed," was held on June 18, 1996, at Spirit Lake, Iowa. This workshop was co-sponsored by the Iowa Department of Natural Resources. Techniques for the production of advanced (127-203 mm; 5.0-8.0 in) fingerling walleye were presented. Participants observed a partial harvest of Welch Lake, a 23-ha (56.8-acre) undrainable pond, with a large seine. A site visit was made to the Spirit Lake State Fish Hatchery to observe procedures for training walleye fingerlings to formulated feed. Fifteen people attended this workshop: four from Iowa, two from Michigan, four from Pennsylvania, and five from Wisconsin.

OBJECTIVE 4

Studies by UW-Madison investigators comparing hybrid and purebred walleye produced from several geographically different stocks of walleye and sauger were recently completed, but the data has not been fully analyzed. To date, hybrid walleye have exhibited superior growth to purebreds at all sizes up to food size. Food size Spirit Lake walleye × Mississippi River sauger gained 1.23 g/day (0.04 oz/day) compared to 0.45 g/day (0.02 oz/day) for purebred walleye. Significant differences in the growth and performance of walleye purebreds and hybrids from different geographic stocks were observed.

Organoleptic trials and proximate analyses of carcass composition revealed little or no difference between purebred and hybrid walleye. Taste panels expressed a high degree of consumer preference for these fish, describing them as firm, flaky, and tender, with an absence of any off-flavors. Proximate analyses indicated that fillets were very low in fat (1.1-1.7%).

WORK PLANNED

OBJECTIVE 1

Investigators at ISU were unable to use a bioenergetics model to calculate feeding rate in Year 1 of the project, because ILNHS collaborators were unable to provide measurements of energy values for walleye and formulated feeds until August 1996. Therefore, in Year 2 a retrospective analysis will be undertaken using energetics data, combined with actual feeding and growth data, to estimate how the bioenergetics model can be used to determine feeding rates. Additional experiments with "feeding the gain" will be completed, and that procedure will be compared with the bioenergetics method, to estimate feeding rates for the production of food-size walleye.

In Year 2, ILNHS researchers will complete their calorimetric studies and modification of the walleye bioenergetics model. Simulations with the model will evaluate potential growth and feeding rates of walleye of various sizes under different aquaculture conditions.

Studies by UNL investigators will focus on evaluating the effects of rearing density on culturing juvenile walleye to food size in tanks, as described in the original proposal. The overwinter survival and growth of juvenile walleye maintained in tanks on well water at 13.3°C (55.9°F) will also be examined. Because of the poor survival of fish in Year 1 and the resulting small numbers of advanced fingerling walleye available, no studies on the production of food-size fish in ponds will be possible in Nebraska in Year 2 of the project. A shortfall in funding also precludes this possibility.

Investigators at UW-Madison, however, will conduct a study to characterize the growth and performance of walleye cultured to food size in ponds in Year 2 of the project. Also, a second experiment to study the spacial requirements of near-food-size walleye in tank culture systems will be conducted. Details on these investigations are outlined in the original project proposal.

OBJECTIVE 2

Investigators at Illinois State University will develop research and extension-oriented publications on the U.S. walleye fingerling market, based on data collected from public and private producers and suppliers, the research findings of NDSU, and other sources. Researchers at NDSU will collect and evaluate secondary data on the export of walleye products from Canada to the U.S., as well as develop a report on the institutional components of the wild-capture fishery in Canada.

Purdue investigators will send Phase 2 surveys to all those firms identified by Phase 1 surveys as restaurants and supermarkets where walleye products were sold in 1996. The Phase 2 surveys will ask targeted questions about walleye purchases and sales. Different surveys have been developed for restaurants and supermarkets. All other types of firms (e.g., fishery products wholesalers, brokers, and food service distributors) will be surveyed with the same, single survey instrument.

OBJECTIVE 3

Two workshops on walleye aquaculture are planned for 1997. Both will be organized by Robert Summerfelt of ISU. The first workshop will be held in Ames, Iowa on February 25, 1997, and will cover the intensive culture of walleye fry. The second workshop will be held at Spirit Lake, Iowa on April 16-17, 1997, and will provide demonstrations of walleye brood stock collection, spawning methods, and egg incubation. In 1997, Kayes of UNL will edit and produce an introductory videotape on the intensive culture of walleye fry.

OBJECTIVE 4
Investigators at UW-Madison will complete the analysis of all data collected under this objective in Year 2 and will submit two manuscripts for publication, comparing the growth, performance, proximate analyses, and organoleptic qualities of hybrid and purebred walleye.

IMPACTS

OBJECTIVE 1
The ongoing project will provide information that can be used to prepare guidelines and tables for predicting growth and determining appropriate feeding rates of juvenile to food-size walleye under different culture conditions, determine whether walleye can be raised to food size under practical production conditions, and help determine which culture techniques can be used to rear this species in a time frame and manner conducive to commercialization.

OBJECTIVE 2
Research to date on this objective has generated no measurable economic impacts. But the research finding on this objective should produce valuable insights on the domestic markets for walleye as food fish, fingerlings, and other intermediate products.

OBJECTIVE 3
The workshops on walleye aquaculture have provided the participants conceptual information as well as demonstrations of important methods. This experience should enhance the ability of participants to learn from reading and doing, as well as undertake more advanced culture technologies.

OBJECTIVE 4
The identification of hybrid walleye × sauger crosses that have superior growth, performance and other characteristics - put to use - should significantly reduce the time and costs required to produce food-size walleye.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix A.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1995-96	$117,897	$143,355				$143,355	$261,252
TOTAL	$117,897	$143,355				$143,355	$261,252

SUNFISH

Project Component Termination Report for the Period
June 1, 1990 to August 31, 1996

NCRAC FUNDING LEVEL: $124,276 (June 1, 1990 to August 31, 1996)

PARTICIPANTS:

Michael L. Hooe	Illinois Natural History Survey	Illinois
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Bruce L. Tetzlaff	Southern Illinois University-Carbondale	Illinois
James R. Triplett	Pittsburg State University	Kansas
David H. Wahl	Illinois Natural History Survey	Illinois
Extension Liaison:		
Joseph E. Morris	Iowa State University	Iowa

REASONS FOR TERMINATION
Objective completed and funding terminated.

PROJECT OBJECTIVE
Determine optimum stocking densities and relationships between temperature and growth for crappie, crappie hybrids, and triploid crappie.

PRINCIPAL ACCOMPLISHMENTS
Hybrid and pure stock crappies were produced at the Sam Parr Biological Station during spring 1993 and 1994 (no black crappie were produced in 1994) by Illinois Natural History Survey (INHS) personnel with assistance from Southern Illinois University-Carbondale (SIUC) researchers. Diploid F_1 hybrid and triploid F_1 hybrid crappies were produced by crossing white crappie females with black crappie males. In spring 1994, ponds were drained and 1,300 - 1,500 fish of each stock (85-100 mm [3.3-3.9 in] total length) were provided for Pittsburg State University (PSU) and 400-500 of each stock were provided for SIUC. In early summer 1994, additional pure stock black and hybrid crappie were provided for SIUC (300-400 of each stock, 100-150 mm [3.9-5.9 inch] total length). Starch-gel electrophoresis for all brood fish confirmed genetic integrity of the fry.

Observations derived from PSU research are:

- Capture and post-transport mortalities were very high, but a small percent of the wild caught white crappie (2%) from summer 1993 survived and showed significant growth. These fish were moved indoors for further feeding trials in a recirculating system.
- Optimum stocking densities were not adequately determined for white crappie. In all cases (1.8 to 5.0 kg/m^3; 0.1-0.3 lb/ft^3) overall survivability in cages was poor. However, survival was high and growth was acceptable in indoor trials at densities of 4-5 kg/m^3 (0.2-0.3 lb/ft^3).
- The high mortalities (57-98%) related to capture and transport of wild caught white crappie during 1993 were reduced to 0% in 1994. Approximately 4,200 fish were transported from the Sam Parr

Biological Station in Illinois to the PSU Research Reserve in Kansas in two hauls of eight hours (702 km; 436 mi) each, without any mortalities. The fish were handled and transported at night with temperatures less than 20°C (68°F) at 4-6 mg/L dissolved oxygen using oxygen diffusers and water treatments of 0.5% salt, PolyAqua™ (0.175-0.375 mL/L), and AmQuel™ (0.125 mL/L). Prior to handling for measurements, fish were anesthetized in Finquel™.

- White crappie, which were wild caught and fed in cages through the summer of 1993, were moved indoors in November and kept in two tanks in a recirculating system at a density of 4-5 kg/m^3 (0.2-0.3 lb/ft^3) for nearly 18 months. During the six feeding trials, only 17 of the 71 fish died; 16 of these were killed accidently by a single high chlorine event.
- Black crappie out-performed both white crappie and hybrid crappie in the second year of the cage culture trials. Black crappies showed the greatest growth rates, feed acceptance, uniformity, and survivability, with white crappies intermediate, and hybrid crappie showing poorest overall performance.
- Fish consumed and grew on 2.5 mm (0.1 in) BiodietJ pellets in both cage trials and recirculating system trials. Examination of the abdominal cavity in all cases revealed fatty livers and the cavity packed with fat.
- Observations of feeding activity in recirculating tanks suggested the formation of feeding hierarchies. Separate feeding experiments in aquaria during the summer of 1994 as part of a National Science Foundation (NSF) research training academy confirmed the presence of a dominance hierarchy.

A growth trial was conducted at SIUC using black, white, and hybrid crappie. White crappie used in the trial had been subjected to a pressure shock; about 66% of them were triploids. Ten 550-L (145.3-gal) circular tanks, each equipped with biofiltration, aeration, and heating and cooling systems, were used in the growth trial. The circular tanks were partitioned into three compartments, with each compartment receiving equal amounts of the inflow water. All three taxa were evaluated in each tank, one taxon per compartment constituted a replicate, 20 fish per replicate. Despite a protracted training period, feed acceptance was poor during the growth trial and none of the taxa grew well at any of the test temperatures. In most cases, test fish actually lost weight during the trial.

A second growth trial was designed so that growth of black and hybrid crappie would be evaluated against hybrid *Lepomis* sunfish (female green sunfish × male bluegill), a sunfish taxa known to be a good performer in recirculating systems under a variety of water temperatures. In this trial, a more protracted period of time was used to attempt to habituate black and hybrid crappies to prepared diets. The initial mean weight of the hybrid sunfish (60.1 g; 2.1 oz) was considerably greater than the black crappie (26.5 g; 0.9 oz) and hybrid crappie (30.4 g; 1.1 oz), but this was largely due to differences in body conformation and condition; there were only small differences in mean initial total length among the hybrid sunfish (14.7 cm; 5.8 in), black crappie (12.5 cm; 4.9 in) and hybrid crappie (13.0 cm; 5.1 in).

The growth trial was terminated at the end of 56 days when it became evident that hybrid crappie were not growing at some of the test temperatures. The extended training period appeared to be successful for black crappie in this trial. Black crappie grew at all test temperatures and had weight gains ranging from about 20 to 45%; hybrid sunfish had weight gains of 48 to 75% at 10 to 18°C (50.0 to 64.4°F). At test temperatures of 10 and 14°C (50.0 and 57.2°F), the hybrid crappie lost weight and showed the poorest growth in comparison to either the black crappie or hybrid sunfish at the other test temperatures. The best growth during the trial was shown by the hybrid sunfish at 18°C (64.4°F). Percent weight gains for black crappie were the highest among the three taxa at 22 and 26°C (71.6 and 78.8°F). However, instantaneous growth rate for black crappie was not better than that for hybrid sunfish at the two highest tested temperatures. Mean survival rate was high for all three taxa with all of the hybrid sunfish and 97% of the other two taxa surviving the trial.

Hybrid sunfish showed their best growth at temperatures of 18°C (64.4°F) or less whereas black and hybrid crappie showed their best growth at temperatures of 18°C (64.4°F) or more. This may be significant, since farmers in our region would have more of an advantage over southern producers with culture animals that grow better at lower temperatures.

Although effective procedures for inducing triploidy in *Lepomis* are available (see the 1994-95 Annual Progress Report), methods developed for crappie have not proved to be as successful. Prior to this study, the best triploid induction rate obtained at SIUC with crappie, using pressure shocks similar to those effective in *Lepomis*, was 66%.

A study conducted at SIUC was designed to develop more effective methods for inducing triploidy in crappie and to test the hypothesis that the temperature at which fertilized eggs are incubated may influence the effectiveness of shocks. The approach used by SIUC researchers was to hold the magnitude (6,000 psi) and duration (3 min) of the pressure shock constant while varying postfertilization shock initiation time (2 to 7 min, tested at 1 min intervals) and the incubation temperature (17, 20, and 23°C; 62.6, 68.0 and 73.4°F) of the developing embryos prior to and during the shock treatment.

Incubation temperature did not affect triploid induction rate but better triploid induction rates were obtained as postfertilization shock initiation times were increased. The most effective shocks for producing triploids in *Lepomis* were initiated at 2 to 3 min postfertilization. Based on frequencies of deformed larvae and triploidy induction rate, the longer postfertilization times were more successful with white crappie eggs. The highest triploidy induction rate SIUC researchers obtained (about 95%) occurred at a postfertilization time of 7 min and at an incubation temperature of 20°C (68.0°F). This suggests that longer postfertilization shock initiation times need to be investigated to optimize triploid induction procedures for white crappie.

IMPACTS

- Findings from PSU indicate survivability in cages is a major problem for cage culture of crappie, but this may be a function of cage design. Consideration of capture and transport methods is vital to minimizing initial mortality losses. PSU researchers determined that black crappie were the most suitable species cage culture.
- PSU researchers have developed capture, transport and handling techniques that can markedly reduce mortality problems associated with crappie in aquaculture

settings.

- Hybrid sunfish had their best growth at temperatures of 18°C (64.4°F) or less whereas black and hybrid crappie had their best growth at temperatures of 18°C (64.4°F) or more. This may be significant, since farmers in this region would have more of an advantage over southern producers with culture animals that grow better at lower temperatures.
- Pressure shock procedures for inducing triploidy in white crappie were developed which yielded more than 90% triploids; it appears that pressure shocks for inducing triploidy in the white crappie need to be applied at a much later time after fertilization, as compared to findings for *Lepomis*.

RECOMMENDED FOLLOW-UP ACTIVITIES

- Cage design needs to be modified and evaluated for crappie culture.
- Continue to evaluate black crappie in recirculating systems.
- Further study needed on transport and stress in crappie.
- Evaluate importance of acclimation in reducing stress.
- Develop feeding strategies that reduce the impact of feeding hierarchies and fat accumulation on growth.
- Re-evaluate density effects associated with stress conditions.
- Determine optimal temperatures for growth and feeding.
- *Lepomis* taxa have not required extended training periods to habituate them to prepared diets. Black, white, and hybrid crappie have been much more difficult to habituate to prepared diets, and they do not feed as aggressively, especially at lower temperatures. This is largely responsible for the poorer overall performance of crappies, as compared to *Lepomis* taxa, under tank culture conditions. There is a need to explore avenues to enhance the response of crappies to prepared diets.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix A.

TOTAL PROJECT SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1990-92	$56,586	$78,088				$78,088	$134,674
1992-94	$67,690	$104,730	$500[a]	$10,000[b]	$4,200[c]	$119,430	$187,120
TOTAL	$124,276	$182,818	$500	$10,000	$4,200	$197,518	$321,794

[a]KOCH Industries - Koch Flexrings

[b]National Science Foundation - STARS Research

[c]$3,000 from Kansas Department of Wildlife & Parks - white crappie and hauling tanks and $1,400 from the City of Pittsburg Water Department - anthracite coal

SUNFISH

Progress Report for the Period
September 1, 1994 to August 31, 1996

NCRAC FUNDING LEVEL: $174,999 (September 1, 1994 to August 31, 1996)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Paul B. Brown	Purdue University	Indiana
Donald L. Garling	Michigan State University	Michigan
Robert S. Hayward	University of Missouri-Columbia	Missouri
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
Joseph E. Morris	Iowa State University	Iowa
Douglas B. Noltie	University of Missouri-Columbia	Missouri
Extension Liaison:		
Joseph E. Morris	Iowa State University	Iowa
Non-Funded Collaborators:		
Denzil Hughes	Farmland Industries, Inc.	Kansas
Fountain Bluff Fish Farms		Illinois
Illinois Department of Conservation	Little Grassy Fish Hatchery, Carbondale	Illinois
Jim Frey	Jim Frey Fish Hatchery, West Union	Iowa
Ron Johnson	Spruce Creek Fish Farm	Minnesota
Myron Kloubec	Kloubec Fish Farms, Amana	Iowa
Missouri Department of Conservation		Missouri
Tribal Council	Red Lake Band Chippewa	Wisconsin
National Biological Service	Midwest Science Center (formerly USFWS	Missouri

PROJECT OBJECTIVES

(1) Produce a production manual, accompanying videos and other information as necessary to demonstrate the technology for culturing centrarchids.

(2) Determine the major nutritional requirements for centrarchids and to compare their growth and performance using available commercial feeds in laboratory and field settings.

(3) Determine the best feeding management strategies for culturing centrarchids in laboratory and field settings.

ANTICIPATED BENEFITS

At the 1993 Program Planning Meeting held in Madison, Wisconsin, the North Central Regional Aquaculture Center (NCRAC) Industry Advisory Council (IAC) specifically requested the development of extension educational materials in the form of a production manual and accompanying video tapes, as a high priority need for demonstrating the commercial feasibility of centrarchid sunfish aquaculture in the region. Such information is needed to enable this industry to enlarge.

Defining the critical nutritional requirements for targeted sunfish will enable development of diets that meet, but not exceed, their requirements. Feed costs are typically the largest annual variable cost; thus, minimizing nutrient concentrations decreases costs without impairing weight gain or health of individuals. Protein requirements of sunfishes are poorly understood, which hinders their economic potential in food fish culture. Accurate estimates of protein requirements for hybrid sunfish that have sex ratios skewed towards males may prove useful in promoting maximal growth rates as well as minimizing feed costs.

Significant progress has been made with regard to sunfish brood stock development (bluegill and black crappie), spawning, acceptance of prepared diets and good growth response. Most of the research and commercial production of sunfish has focused on utilizing pond systems (extensive aquaculture). However, to a lesser extent this same effort has been directed at intensive aquaculture. With a better understanding of the early life stage feeding strategies the aquaculture industry will be able to broaden the scope of sunfish aquaculture to include rearing these fish under intensive conditions.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

During the 1994-96 period University of Nebraska-Lincoln (UNL) researchers were to produce two 10-20 minute educational video tapes on selected topics covered in the new sunfish production guide. However, due to time constraints at UNL these videotapes are postponed until 1997. Michigan State University (MSU) and ISU personnel have completed drafts of the new sunfish culture guide. The individual chapters will be reviewed during winter 1996; the guide is scheduled for completion by summer 1997.

There have been numerous sunfish hybrids produced by both researchers and private aquaculturists; these hybrids have varying percentages of male offspring and growth rates. The hybrid sunfish used by NCRAC researchers is the F_1 offspring resulting from crossing a female green sunfish (*Lepomis cyanellus*) with a male bluegill (*L. macrochirus*).

At Southern Illinois University-Carbondale (SIUC), researchers used practical diets containing crude protein levels of 32, 36, 40, and 44% and compared their ability to promote growth of hybrid sunfish in two culture systems: recirculating culture system and culture ponds.

<u>Recirculating Culture System</u>

Year 1 adult hybrid sunfishes (source: Fountain Bluff Fish Farms, Illinois; mean initial weight = 37.1 g [1.3 oz]) were stocked at a density of 28 fish per 300 L (79.3 gal) circular tank (three replicates per treatment). Flow rates were 30 L/min (7.9 gal/min) and water temperature was maintained at approximately 24°C (75.2°F). Feeding rates were 2%/day divided into two feedings during the 98-day growth trial. Survival ranged from 93 to 100% and did not differ significantly between treatments ($P > 0.05$). Weight increase and feed conversion efficiency were highest for the 44% crude protein diet and were significantly greater than the 36 and 32% diets (0.39 versus 0.33 and 0.27, respectively). These data indicate that optimal crude protein levels are likely to be in excess of 40% for hybrid sunfish in recirculating culture systems. The poor feed conversion efficiencies observed may be due to the experimental animals being sexually mature and directing considerable amount of their food intake towards gamete production and reproductive behavior. Proximate analysis of feeds and fish whole bodies is now under way.

Pond Culture

Juvenile hybrid sunfish (mean weight = 12 g; 0.04 oz), were stocked (May 23, 1995) at a rate of 5,504 fish/ha (2,228 fish/acre), into 16 ponds averaging 0.04 ha (0.10 acre) (four treatments/four replicates per treatment). Ponds were supplied with one of four practical diet formulations containing crude protein levels of 32, 36, 40, or 44%. Feeding rate was initially 3% of the estimated biomass once a day except on days of sampling. All ponds exhibited nest building activities by June 6 and recruitment of F_2 hybrids in some ponds was apparent by July 18. Feeding rates were reduced to 2% (August 15 through September 26, 1995) when a large amount of feed was noticed left from the previous feedings. This reduction in feeding activity coincided with high temperatures of 30°C (86°F). Resulting data was of limited use due to natural recruitment of F_2 offspring.

Year 1 adult hybrid sunfishes (source: Fountain Bluff Fish Farms, Illinois; mean initial weight = 40 g; 1.41 oz) were stocked April 16, 1996 into 16 ponds averaging 0.04 ha (0.10 acre) (four treatments/four replicates per treatment). Stocking density was 13,875 fish/ha (5,615 fish/acre). All ponds were limed and fertilized two weeks prior to stocking to promote plankton blooms. Feeding to apparent satiation was carried out two times per day except during times of rain and strong winds. Aeration to ponds with dissolved oxygen levels of less than 2.0 mg/L was applied with a tractor driven paddle wheel. Harvest is to be carried out October 29, 1996 following a complete draw down.

Researchers at MSU have empirically determined the optimal energy level for growth and protein retention in 125 mm (4.9 in) hybrid sunfish utilizing a saturation kinetics model for curve fitting. Results demonstrate the semi-purified diet developed for these trials is well accepted by these fish; this results in a slightly lower but comparable growth to that obtained using a commercial control diet. There were no significant differences in growth or net protein utilization (NPU) between the experimental diets and the control diet; hence the semi-purified diet is suitable for the remaining phases of these trials.

The whole body indispensable amino acid (IAA) profile of 50 and 125 mm (2.0 and 4.9 in) hybrid sunfish, green sunfish, and bluegill has been determined. The data obtained has been used for predicting the IAA requirements for these species using the A/E ratio ([individual IAA content/total IAA content+Cys+Tyr] × 1000) of whole fish tissue. These predicted IAA requirements will be used in the preparation of diets for the remaining phases.

MSU researchers are currently beginning a trial evaluating growth, NPU, protein retention, and energy retention in 125 mm (4.9 in) hybrid sunfish fed graded levels of protein in isocaloric diets using the optimal energy level predicted in the previous trial. Diets have been formulated to meet IAA requirements for hybrid sunfish determined by researchers at Purdue University (Purdue) with the unknown requirements incorporated at levels predicted by the A/E ratio. This trial will be completed the first of the year; results will be used to predict the optimal P:E ratio for 125 mm (4.9 in) fish.

Research at Purdue was initially focused on quantifying key nutritional requirements of hybrid sunfish. Through three separate studies with the hybrid sunfish, growth was relatively low despite offering a broad variety of diets. Prior to conducting the next series of studies on critical nutritional requirements, an evaluation of pure bluegill was conducted. Growth of pure bluegill was double the growth observed with hybrid bluegill. The studies were conducted in the same experimental systems in the same conditions with the same broad variety of feeds. There was also differential use of commercial diets. Results of those studies clearly indicated that diets formulated for trout and salmon were better than diets formulated for catfish. Further, there were clear distinctions within the trout diets. That is, all trout diets are not the same nor is the response in the hybrid sunfish comparable to the pure bluegill. Both the optimum lipid:carbohydrate ratio and quantitative phosphorus requirements are underway. The optimum lipid study was expanded to include both hybrid sunfish and bluegill. Results will be known by December 1996.

Researchers at the University of Missouri have examined the potential to increase growth rates of hybrid sunfish during grow-out by using feeding schedules that bring out these fishes' compensatory growth response (increased growth following a period of fasting). Hybrid sunfish were held individually in experimental enclosures submerged in larger water-recirculation tanks. Water temperature was maintained at 24°C (75.2°F) as was a 15-h light/9-h dark photoperiod regime. Mealworms (*Tenebrio molitor*) were used as the food in these initial experiments so that daily consumption by individual fish could be accurately determined. Over the 105 day experiment, mean growth rates of hybrid sunfish in the 2 and 14 day no feeding cycle groups were 2.1 and 1.5 times faster than the controls that were fed *ad libitum* every day.

These results represent the first demonstration that fish can be grown significantly larger than daily-fed controls over identical time periods by eliciting the compensatory growth response. Growth improvements from compensatory growth appeared to result from increases in both consumption rate and growth efficiency. While best results were observed for the shortest off/on feeding cycle, there was some suggestion from growth responses that longer off/on cycles (>14 days) may be of value.

The primary goal of the University of Wisconsin-Milwaukee (UW-Milwaukee) researchers was to utilize the early life stage feeding technology developed for yellow perch and apply this approach to centrarchids, specifically, black crappie. The researchers selected two early life stages as their starting points for the development of intensive aquaculture strategies. Young-of-the-year (YOY) Wisconsin pond-raised black crappie (N = 1,200) were obtained in fall 1994. Under laboratory conditions these fish accepted adult frozen brine shrimp as a transitional food within 3 days and were habituated to commercial starter feed within 14 days. Survival to present was greater than 65%. In addition, UW-Milwaukee researchers obtained several hundred YOY black crappie from a commercial producer in

Iowa. Initially these fish were fed "green tank" water organisms, which included copepods, ostracods and smaller cladocerans. These organisms are all much larger than those fed to yellow perch at first feeding. Later on, brine shrimp nauplii (BSN) (*Artemia franciscana*) and a beef liver mixture was added to the feeding schedule. This group of black crappies habituated to a formulated starter diet within 26 days. This group of fish (*N* = 73) was terminated on September 25, 1995; mean length and weight was 66.8 mm (2.63 in) and 3.92 g (0.14 oz), respectively.

Since the last report, UW-Milwaukee researchers have continued to expand their efforts to habituate YOY black crappie to formulated diets. Past efforts to spawn adults in the laboratory or to collect wild adults have not been successful. They have continued to maintain the group of YOY black crappies acquired in October 1994 for use as a captive brood stock. These fish were habituated to commercial formulated diet within 14 days of arrival and have been maintained on a rearing regime that is intended to promote gonadal development. It is anticipated that these fish will be fully mature and available for spawning in the spring of 1997.

As a back-up to their efforts to produce YOY from laboratory and wild spawns, UW-Milwaukee researchers obtained 2,741 pond-spawned YOY black crappies (mean length = 26 mm; 1.0 in; mean weight = 0.1-0.5 g; 0.004-0.018 oz) from the Gavin's Point National Fish Hatchery in Yankton, South Dakota. The fish were stocked into a circular flow-through rearing tank and the photoperiod was set at 13-h light. When offered BSN on the day of arrival approximately half the fish accepted the food. Trial feedings with formulated diets on the day of arrival were unsuccessful. These fish took longer to habituate to formulated diet than either the slightly larger YOY brought to the lab in October 1994, those habituated to a formulated diet within 14 days, or the larval crappies tested in July 1995 that habituated to formulated starter diet within 26 days. These results suggest that there is a strong preference for BSN, and that habituation is not readily achieved by merely offering the formulated diet along with the transitional live food. This group of YOY crappie was very reluctant to feed in the presence of observers. Although there was limited interest in formulated foods as early as 6 days after the beginning of the trial, the general population consumed mainly the BSN. Full habituation to formulated diet appeared to closely follow the forced restriction of the live food. Survival during the trial was excellent, 99% over a rearing period of 103 days. UW-Milwaukee researchers intend to continue rearing this group of fish to demonstrate the growth that can be achieved under intensive flow-through culture with formulated diets. Growth information has been obtained at 0 days (26 mm; 1.0 in); 12 days (34 mm; 1.3 in), 57 days (55 mm; 2.2 in) and 105 days (75 mm; 3.0 in) since the start of the trial.

One objective of the ISU researchers was to spawn sunfish out-of-season through temperature and photoperiod manipulation under laboratory settings (bluegill and hybrid sunfish). ISU researchers stocked adult fish at a ratio of two males to four females (170 g; 6.0 oz) per 640 L (169 gal) tanks in a recirculation system. After an acclimation period, temperature and photoperiod were maintained at 24°C (75.2°F) and 14-h light/10-h dark. They were able to spawn bluegills during a six month period (December 1994 - May 1995); 40 spawns averaging 20,000 larvae each were obtained from 24 females. Hybrid sunfish were successfully produced the following fall.

The second objective of the ISU study was to develop a procedure for tank-rearing larval bluegill and larval hybrid sunfish. In the first set of experiments, seven commercial diets were used for feeding larval bluegill from the onset of exogenous feeding to 28 days posthatch. Although all diets were consumed by the larvae, none were digested and survival was essentially zero. In the next set of experiments, bluegill larvae were able to digest commercial diets by feeding them BSN for an initial 7 day period and then switching to commercial feed over a 3 day period. Using this protocol, three feeds (Fry Feed Kyowa® B-250, Hatchery Encapsulon® Grade II, and Larval AP-100®) were compared over a 28 day interval. There were no significant ($P \leq 0.05$) differences in growth (length and weight) among the three diets at the end of 28 days, but survival was significantly higher for fish fed Fry Feed Kyowa® B-250. In another experiment, Fry Feed Kyowa® B-250 was fed to larval bluegill after feeding them BSN for 3, 7, or 14 days with an additional 3 day weaning period with mixed feeding. Larvae fed BSN for 14 days had significantly higher growth and survival than did larvae in the 3 day and 7 day treatment groups. In a final experiment, Fry Feed Kyowa® B-250 was fed to larval hybrid sunfish after feeding them brine shrimp for 0, 3 or 7 days with an additional 3 day weaning period of mixed feeding. The larvae fed brine shrimp for only 0 or 3 days initially grew slower than did the larvae in the 7 day treatment; however, by the end of the experiment (28 days posthatch), there were no significant differences among lengths or weights in the three treatments. At 28 days posthatch, larvae fed brine shrimp for 7 days had a significantly higher survival rate than larvae in either the 0 or 3 day treatments. Results indicate that the protocol for tank-rearing larval bluegill and larval hybrid sunfish should include using brine shrimp prior to using a commercial diet. It appeared that larval hybrid sunfish could digest the commercial diet at the onset of exogenous feeding. However, without BSN much lower survival rates resulted. Survival rates of about 25 and 37% can be expected for bluegill and hybrids, respectively, by following this protocol.

WORK PLANNED

UNL will produce videos in 1997 related to the upcoming sunfish culture guide. This guide will be competed during 1997.

Critical nutritional requirements for targeted species reduces feed costs and overall cost of production of fishes will continue to be defined by Purdue and MSU researchers. SIUC researchers will compile data from their recirculation and pond studies. These data will be important pieces of information for manufacturers of feed.

UW-Milwaukee researchers will attempt the laboratory spawning of their captive black crappie brood stock by manipulating temperature and photoperiod. If necessary they will use spawning induction substances in spring 1997. If successful, the YOY black crappie produced from this brood stock will be used in the new NCRAC sunfish project. Researchers at ISU will continue to do research into sunfish culture by growing hybrid sunfish up to food-size and to evaluate a sunfish hybrid produced by crossing a female redear sunfish (*L. microlophus*) with a male bluegill.

IMPACTS

- Coupled with the NCRAC-sponsored development of improved intensive larval sunfish culture techniques at ISU under the direction of Morris, commercial fish farmers have the tools to establish stocks of polyploid sunfishes.
- NCRAC funding permitted SIUC to leverage funding from the American Fishing Tackle Manufacturing Association to evaluate benefits of triploid sunfish in recreational fishing ponds. The supply of triploids to recreational fisheries could provide a new market for regional producers.
- Developing diets specifically for targeted species results in maximum performance at the lowest possible cost. Purdue research directed at minimizing costs of feeds will help to maximize profit to the producer.
- It now appears that the intensive culture technology developed for yellow perch can be applied to black crappie. Also, YOY (30-60 day old) pond-produced black crappie can habituate to prepared diets within 26 days; YOY (100 day old) pond-produced black crappie can habituate to prepared diets within 14 days. The potential for the intensive culture of black crappie looks very promising.
- It is now possible to produce bluegills and hybrid sunfish in the laboratory out-of-season by manipulation of temperature and photoperiod without the use of hormones. This protocol allows for the production of these fish, regardless of season, for both laboratory studies and aquaculture stocking.
- The potential for the intensive culture of black crappie will provide an alternative to seasonal pond rearing and could expand the growth and production to an annual basis in conjunction with recirculating aquaculture system technology.

PUBLICATIONS

See Appendix A.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1994-96	$174,999	$177,300	$12,012[a]			$189,312	$364,311
TOTAL	$174,999	$177,300	$12,012	$0	$0	$189,312	$364,311

[a]Farmland Industries, Inc.

SALMONIDS

Project Component Termination Report for the Period
March 1, 1990 to August 31, 1996

NCRAC FUNDING LEVEL: $79,799 (March 1, 1990 to August 31, 1993)

PARTICIPANTS:

Anne R. Kapuscinski	University of Minnesota	Minnesota
James E. Seeb	Southern Illinois University-Carbondale	Illinois
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Extension Liaison:		
Ronald E. Kinnunen	Michigan State University	Michigan
Non-funded Collaborators:		
Hugo Kettula	Seven Pines Trout Hatchery, Lewis	Wisconsin

REASONS FOR TERMINATION
Objective completed and funding terminated.

PROJECT OBJECTIVE
Evaluate all-female diploids and all-female triploids, and use brood stock developed in the region to produce all-female diploid and all-female triploid trout populations.

PRINCIPAL ACCOMPLISHMENTS
Efforts culminated in a 265-day grow-out trial at Southern Illinois University -Carbondale (SIUC) in which the performance of all-female triploid, all-female diploid, and mixed-sex diploid rainbow trout were compared. The results of the grow-out trial vindicated the North Central Regional Aquaculture Center (NCRAC) interest in all-female and all-female triploid rainbow trout.

The grow-out trial was initiated with approximately 100-g (3.53-oz) fish. Progeny from three families of all-female triploid and progeny from three corresponding full-sib families of all-female diploid trout were used in the trial. The mixed-sex diploid trout were progeny of three families that were half-sibs of the corresponding all-female diploid and all-female triploid families. Trout used in the grow-out trial were from crosses made at the University of Minnesota (UM), where they were also reared to 10 to 20 g (0.35 to 0.71 oz) prior to shipping to SIUC for the grow-out trial.

A water re-use system and twelve raceways were used in the grow-out trial, four raceways per treatment. Each raceway was stocked with 25 trout, but stocking densities were reduced to 15 trout per raceway on day 180 of the trial. Mean initial weights were 93.5, 84.2 and 111.6 g (3.30, 2.97 and 3.94 oz) for the mixed-sex diploid, all-female diploid, and all-female triploid, respectively. Mean initial lengths and weights did not differ among the three groups.

Growth was linear during the grow-out trial. Absolute growth rate was highest for the all-female triploid, intermediate for the all-female diploid, and lowest for the mixed-sex diploid, 2.38, 1.78, and 1.58 g/day (0.08, 0.06, and 0.05 oz/day), respectively (P <

0.025). Mean final weights were 520.5 g (1.15 lb) for the mixed-sex diploids, 567.5 g (1.25 lb) for the all-female diploids, and 748.9 g (1.65 lb) for the all-female triploids.

No significant differences ($P > 0.05$) were found in survival, food conversion ratios, condition factor, liver somatic index, visceral fat weight or dress-out percentage yield among treatments. By day 180 of the growth trial, most of the males in the mixed-sex diploid group were sexually mature, while the mixed-sex diploid females and the all-female diploids were still maturing. Based on subsamples of trout sacrificed at that time; mean gonadosomatic index for mixed-sex diploid males was 3.13, while values for the mixed-sex diploid females, all-female diploid and all-female triploid trout were 1.13, 1.86 and 0.38, respectively.

All-female diploid and all-female triploid trout show promise for practical trout farming. All-female trout production eliminates the problem of early maturation in males which leads to poor flesh quality and undesirable appearance, and results indicate that all-female diploid trout grow better than mixed-sex diploid trout. All-female triploid trout, however, grew the fastest. Farmers should consider all-female triploid trout production, especially those targeting markets utilizing larger trout.

The all-female triploid trout grew faster than the all-female diploids and mixed-sex diploids in growth trials, but aquaculturists also need to know how triploids perform in other respects to make decisions regarding their production and use. Many culturists produce food fish, but fingerling production for recreational fish stocking programs provides another market outlet for cultured fish. Harvest, crowding, handling, and hauling are problems inherent to fish-farming as well as to fish stocking programs.

Survival of triploids was evaluated during simulated transportation in one experiment with 33-g (1.16-oz) chinook salmon, another with 14-g (0.49-oz) coho salmon, and a third with 1.5 g (0.05-oz) rainbow trout. Triploids were produced via heat shocks. Both diploids and triploids were stocked into replicate containers in each experiment at densities recommended for transporting salmonids. Mortality was recorded every 30 min. Diploids had been exposed to heat shocks in the chinook salmon experiment, but not in the other two experiments.

Triploid chinook salmon died faster than diploids ($P < 0.005$). The maximum difference between mortality distributions (D_{max}) was 21.7%. Coho salmon triploids also died faster than diploids ($P < 0.005$). D_{max} occurred at 660 to 690 min, when 74% of the triploids were dead but only 47% of the diploids were dead. D_{max} in the rainbow trout experiment was only 6.7% ($P > 0.05$), indicating no difference. These results indicate that triploid rainbow trout can tolerate extreme environmental conditions about as well as diploids.

The reduced survival found for triploid chinook and coho salmon indicates that survival may be lower for triploids of these two species under some aquacultural conditions, and survival may also be reduced after stocking. Diminished survival, however, does not necessarily preclude the use of triploids in situations where natural stock protection is an important consideration in stocking programs or in site-selection for an aquaculture installation.

Early growth and survival was also examined for mixed-sex diploid, all-female diploid, and all-female triploid rainbow trout at UM and SIUC during earlier periods of this research. Mixed-sex diploids and all-female diploids early growth and survival was also examined by Seeb at the Fort Richardson State Fish Hatchery, Anchorage, Alaska, under practical fish culture conditions.

Survival through the eyed stage was relatively high (83 to 97%) for mixed-sex diploid, all-female diploid, and all-female triploid eggs in the UM study. Survival through the eyed stage was significantly lower for all-female triploids, in comparison to mixed-sex diploids, but only by approximately 13%. All-female triploids survived as well or better than mixed-sex diploids and all-female diploids after hatching, and growth through 14 weeks did not differ between mixed-sex diploid, all-female diploid, and all-female triploid trout ($P > 0.05$).

Cumulative mortality from fertilization through hatching, yolk-sac absorption, and up to 0.5 g (0.02 oz) was about 30% higher ($P < 0.05$) for all-female triploids, as compared to mixed-sex diploid and all-female diploid trout in the SIUC trial. Differences in mortality appeared to primarily occur prior to hatching and, secondarily, during yolk-sac absorption. These results, in conjunction with those obtained at UM, suggest that the triploidy induction procedure, the heat shock, was the primary factor responsible for the increased mortality. Mortality did not differ ($P < 0.05$) after hatching through growth to 0.5 g (0.02 oz) at SIUC.

A 240-day growth trial initiated with the mixed-sex diploid, all-female diploid, and all-female triploid trout once they reached 0.5 g (0.02 oz) was then conducted at SIUC. There were no mortalities in mixed-sex diploid, all-female diploid, and all-female triploid trout during the 240-day growth trial. This pattern of similar survival after yolk-sac absorption between diploid and triploid rainbow trout was confirmed in the UM study, in the simulated transportation experiment (above) and in the grow-out trial. The trout grew from 0.5 g (0.02 oz) to approximately 2.7 to 3.0 g (0.10 to 0.11 oz) during the trial. Growth did not differ between mixed-sex diploid, all-female diploid, and all-female triploid trout ($P <$ 0.05). Feed conversion efficiencies (wet weight of fish/dry weight of feed) did not differ during the 240-day growth trial; they ranged from 93% for the mixed-sex diploids to 99% for the all-female diploids. Feed conversion efficiency was 96% for the all-female triploid trout.

Findings in the UM and SIUC studies show that survival in triploid trout is somewhat diminished prior to the onset of exogenous feeding. However, the economic loss associated with this additional mortality in all-female triploid trout prior to exogenous feeding is minor, since numbers of eggs generally are not limiting in rainbow trout culture, and relatively little investment in rearing costs occurs prior to feeding. The additional production costs associated with this early mortality is more than offset by the better growth during grow-out. All-female triploid trout do not undergo sexual maturation, so the retention of good flesh quality and appearance is reason enough for producing them.

The Fort Richardson State Fish Hatchery study confirmed no differences in survival between mixed-sex diploid and all-female diploid trout following yolk-sac absorption and through 349 days of age; survival for mixed-sex diploid and all-female diploid trout exceeded 90% during the trial. The growth trial was divided into three phases (83, 148 and 349 days) because numbers of trout per replicate were reduced twice as they grew. Mean weights for the mixed-sex diploid and all-female diploid trout, respectively, were 4.1 g (0.14 oz) and 3.7 g (0.13 oz) at 83 days; 32.4 g (1.14 oz) and 27.8 g (0.98 oz) at 148 days; and 81.0 g (2.86 oz) and 67.8 g (2.39 oz) at 349 days of age. Growth did not statistically differ between mixed-sex diploid and all-female diploid trout. Food conversion efficiency also did not differ between mixed-sex diploid and all-female diploid trout; it ranged from 65.3 to 73.7% during the first two phases.

The results of the Fort Richardson State Fish Hatchery study were consistent with findings in the UM and SIUC pre-maturation trials with rainbow trout. Prior to the onset of sexual maturation, mixed-sex diploid and all-female diploid trout differ little in survival and growth.

To determine why all-female diploid and triploid rainbow trout grow faster than mixed-sex trout during grow out, two lines of investigation were pursued at SIUC. One investigation examined daily activity patterns and activity intensity in mixed-sex diploid and all-female diploid trout, and the other studied muscle cell growth dynamics in diploid and triploid trout.

Although adult all-female diploid trout showed activity levels higher than mixed-sex diploids at lower water temperatures, the reverse was true at the higher temperatures (above 12.5°C; 54.5°F) at which this species is typically cultured. This means that all-female diploid trout have more dietary energy available for growth at culture temperatures, because they waste less energy on nonessential swimming. Another, and perhaps the most important, reason why all-female diploids outgrow mixed-sex diploids is that rainbow trout males mature and slow their growth earlier than females, due to the investment of energy into gonadal tissues and development of secondary sexual characteristics.

Muscle fiber growth dynamics in triploids is of interest, because whole-body growth occurs via two processes: (1) increased size of muscle fibers or hypertrophy, and (2) increased numbers of fibers or hyperplasia. Fish show what has been referred to as indeterminate growth; i.e., they are capable of hyperplastic and hypertrophic growth even after adulthood, whereas postnatal growth occurs only by hypertrophy in other vertebrates. In fish, however, hyperplastic growth eventually ceases, but the longer a species is capable of hyperplastic growth, the larger its ultimate size and the faster its growth.

Muscle fiber growth dynamics were examined in triploid rainbow trout using both biochemical (RNA, DNA, and protein measurements) and histological (muscle fiber diameter sizes) approaches. It is believed that this is the first time that muscle cell growth dynamics has been investigated in any triploid animal.

Triploid trout less than 30 cm (11.8 in) in total length showed muscle fiber size distributions which differed from diploids. Specifically, triploid hyperplastic muscle fibers were larger than those of diploids. However, the difference in fiber size distributions diminished as the trout grew, and it disappeared in larger trout where hyperplasia plays only a small role in growth. This increase in hyperplastic muscle fiber size results in a decrease in the cellular surface area to volume ratio which may be unfavorable to metabolic exchanges between the cell and its external milieu. Poorer survival in triploids during early life may be linked to the increase in hyperplastic muscle fiber size. Another potential disadvantage for triploids is that their muscle cells (which are multinucleate) appear to have fewer nuclei per muscle cell. This study also showed that larger diploid and triploid rainbow trout have similar growth capacities; i.e., they are capable of growing to the same maximal size and at the same rate, all else being equal. This suggests that the superior growth in all-female triploid trout is not due to any inherent differences in growth capacity. Rather, it is probably because triploid female rainbow trout do not direct dietary energy into gonadal growth and the development of secondary sexual characteristics.

SIUC researchers also found that RNA concentrations did not differ between diploids and triploids growing at the same rate and that protein concentrations did not differ in diploid and triploid muscle tissues. This indicates that the rate of protein synthesis does not differ between diploids and triploids, despite the latter having fewer nuclei per cell. This further suggests that genes of the third set of chromosomes in triploids are expressed to compensate for the reduced number of nuclei in triploid muscle cells. Meiotic gynogenesis, followed by sex reversal, is an important initial step in the production of brood stock for all-female rainbow trout production, because it ensures all XX progeny. However, meiotic gynogens exhibit poor viability and growth, because they are highly inbred; a level of inbreeding roughly equivalent to several generations of full-sib matings. Gynogenesis followed by sex-reversal does ensure the production of 100% all-female progeny, but it is inefficient to use gynogenesis for the continuing production of brood stock. A far better approach is to sex-reverse all-female progeny produced from an outcross between an XX sex-reversed male gynogen and a normal XX female, because the outcross eliminates inbreeding depression. The progeny can thus be much more successfully and efficiently raised to sexual maturation.

SIUC researchers shipped about 500, 5-cm (2.0-in) sex-reversed XX males to the Seven Pines Trout Hatchery. Since these were the progeny from an outcross between XX Isle of Mann males and XX Seven Pines females, their viability should be excellent. However, only about 20 pairs of trout were used to produce the 500 progeny, substantially lower than the number of brood stock required to ensure sufficient genetic diversity for aquacultural purposes. Genetic diversity needs to be increased in the XX male brood stock at some future time before it can truly be said that a regional brood stock for all-female production has been established.

IMPACTS

Studies of all-female diploid rainbow trout demonstrate that:

- All-female diploid trout grow and survive as well as mixed-sex diploid trout during early life.
- Declines in flesh quality and appearance due to sexual maturation occur earlier in mixed-sex diploid than all-female diploid trout.
- All-female diploid trout grow faster than mixed-sex diploids through grow out, and survival is similar.
- All-female diploid trout show reduced non-essential activity at culture temperatures above 12.5°C (54.5°F), possibly accounting in part for their better growth as compared to mixed-sex diploid trout.

Studies of all-female triploid rainbow trout showed that:

- All-female triploid trout show somewhat reduced survival through yolk-sac absorption; production of all-female triploids via crosses of tetraploids with diploids may reduce or eliminate this problem.
- Survival beyond yolk-sac absorption in all-female triploid trout is similar to mixed-sex diploid trout under normal conditions, and it was also similar under adverse conditions in simulated transportation tests.
- All-female triploid trout showed the anticipated reduced gonadal growth.
- All-female triploid trout were clearly superior to mixed-sex diploids and all-female diploids during grow out through market size.
- Studies of muscle cell growth dynamics indicate that there is no inherent difference in the capacity for growth between diploid and triploid rainbow trout; the superior growth in all-female triploid trout appears to be primarily due to their failure to undergo sexual maturation.
- All-female triploid trout production may be the best choice for regional farmers, given their superior growth over mixed-sex diploid and all-female diploid trout.
- All-female triploid trout production appears to be an especially strong option for farmers interested in producing a larger trout, since they grew faster than mixed-sex diploid and all-female diploid trout in these studies, and all-female triploids should not show declines in flesh quality and appearance which accompany sexual maturation in mixed-sex diploid and all-female diploid trout.

RECOMMENDED FOLLOW-UP ACTIVITIES

All-female diploid and triploid rainbow trout show considerable promise for commercial aquaculture, especially in regions where breeding programs have not selected for stocks which mature at a larger size. Female rainbow trout mature at a larger size than males, so all-female diploid production reduces problems such as the declines in flesh quality and appearance prior to market size. All-female diploid trout also grew faster than mixed-sex diploid trout to market size in these studies. Producers interested in producing larger trout should give strong consideration to all-female triploid production, since the problems associated with sexual maturation appear to be forestalled indefinitely, and all-female triploid trout grew the best through grow out in these studies.

Cost-effective all-female triploid and all-female diploid production in the North Central Region will necessitate farmers to develop brood stocks for producing all-female diploid and all-female triploid fry. This will require production of sex-reversed gynogens for all-female production and tetraploid production for crosses with diploids to produce triploids. Field trials which compare all-female triploid, all-female diploid, and mixed-sex diploid trout would enable farmers to determine the best choice for production stocks in commercial aquaculture settings.

Hence, the following activities are suggested for follow-up:

(1) further production of sex-reversed gynogen brood stocks,
(2) production and evaluation of tetraploid brood stocks, and
(3) production trials for mixed-sex diploid, all-female diploid, and all-female triploid trout in commercial aquaculture settings.

PUBLICATIONS, MANUSCRIPTS, OR

PAPERS PRESENTED

See Appendix A.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1990-91	$39,299	$22,669		$3,000[a]		$25,669	$64,968
1991-92	$20,500	$13,265		$5,000[b]		$18,265	$38,765
1992-93	$20,000	$14,960				$14,960	$34,960
TOTAL	$79,799	$50,894		$8,000		$58,894	$138,693

[a]Seven Pines Trout Hatchery for time, use of rearing facilities, feed, and fish
[b]Alaska Fish and Game for time, use of rearing facilities, feed, and fish.

SALMONIDS

Progress Report for the Period
September 1, 1994 to August 31, 1996

NCRAC FUNDING LEVEL: $200,000 (September 1, 1994 to August 31, 1996)

PARTICIPANTS:

Terence B. Barry	University of Wisconsin-Madison	Wisconsin
Paul B. Brown	Purdue University	Indiana
Konrad Dabrowski	Ohio State University	Ohio
Donald L. Garling	Michigan State University	Michigan
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Ronald R. Rosati	Illinois State University	Illinois
Extension Liaison:		
Ronald E. Kinnunen	Michigan State University	Michigan
Non-funded Collaborators:		
Hugo Kettula	Seven Pines Trout Hatchery, Lewis	Wisconsin
T.R. Muench	Purdue University	Indiana
I. Navarro	University of Barcelona	Spain
Nebraska Game & Parks Commission	Calamus State Fish Hatchery, Burwell	Nebraska
Forrest Sawlaw	Archer Daniels Midland, Peoria	Illinois
K. Warner	National Center for Agricultural Utilization ARS, USDA, Peoria	Illinois
M. Randall White	Purdue University	Indiana
Wisconsin Department of Natural Resources	Lake Mills State Fish Hatchery	Wisconsin
Y. Victor Wu	National Center for Agricultural Utilization, ARS,USDA, Peoria	Illinois
Michael Wyatt	Sandhills Aquafarm, Keystone	Nebraska

PROJECT OBJECTIVES

(1) Develop practical rainbow trout diets using regionally available feed ingredients, including fish meal analogs.

(a) Evaluate the effects of feed binders in diets formulated from locally available plant ingredients on trout performance and on the stability of trout feces to enhance the removal of solids from hatchery effluents.

(b) Evaluate the effectiveness of phytase treatment of plant feed ingredients on phosphorus and protein availability to trout.

(c) Develop and evaluate fish meal-free diets using regionally available feed ingredients.

(2) Use the stress response as a selection tool for developing strains of trout having improved performance under conditions found in the North Central Region (NCR).

(3) Use stress and performance responses in trout to evaluate culture system design and operation under practical conditions.

ANTICIPATED BENEFITS

The development of less-polluting, lower-cost diets from regionally available ingredients will benefit existing aquaculturists facing stricter regulatory pressures to reduce waste nutrients in effluents, as well as new aquaculturists facing increasingly complex permitting processes. Using regionally available plant protein and animal by-product protein sources as substitutes for fish meal in trout diets should reduce the cost of feed manufacture (by reducing both ingredient and transportation costs) and help produce diets that are less polluting. The development of regional trout strains selected for superior growth and stress resistance when reared under the distinctive aquaculture conditions found in the NCR (i.e., relatively small-sized farms, low water flows, and variable water temperatures) will improve the overall production efficiency in both private and public sector facilities. In addition, sources of quality trout eggs from within the region will reduce the region's reliance on imported eggs, and help alleviate concerns about disease transmission. An increased understanding of how rearing density, loading, and water turnover rates influence fish growth, feed conversion, and disease resistance will improve overall production efficiency and help reduce effluent wastes. The improved feeds, fish strains, and rearing methods identified in this study will benefit private fish farmers, public sector hatchery managers, feed manufacturers, aquaculture facility designers, and other user groups.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Investigators at Michigan State University (MSU) conducted research to determine if mineral and protein availability could be improved in plant-based rainbow trout diets by pre-treating dietary soybean meal and/or corn gluten meal with the enzyme phytase. Phytase hydrolyzes phytate, a molecule which binds minerals (such as Zn and P) and proteins in the intestine. Soy-corn gluten meal-based diets were or were not pre-treated with phytase, and were or were not supplemented with 50 ppm zinc. The activities of the digestive proteases carboxypeptidase A (CPA) and B (CPB) were measured in pyloric fecal extracts because the enzymes contain a zinc atom at the active site. Intestinal alkaline phosphatase (ALP) activity was measured because ALP is also a zinc-dependent digestive enzyme and is associated with phosphorus digestion in vertebrates. Plasma was also collected for insulin assay because insulin is stored on a zinc-based crystal in the pancreatic cell. Insulin is important for protein utilization in fish. The feeding phase of the experiment was completed in July 1996. Tissue extracts were tested for CPA and CPB and ALP activities. Whole body, gill filament, and bone samples are currently being prepared for mineral analysis. Plasma samples have been sent to a collaborator, Dr. I. Navarro at the University of Barcelona, for insulin assay. The insulin results should be available by January 1997. Standard assays for CPA and CPB used with other fish species were modified for rainbow trout--the first CPA and CPB assay methods for this species. Preliminary results indicate that diets had no effect on fish moisture content, condition factor (k), or length-weight relationship. The evaluation of growth data was complicated by mortalities during the study; analysis of growth data is not yet available. Mortalities were not diet-related.

Researchers at Ohio State University (OSU) compared the growth rates of rainbow trout fed five different diets in which fish meal protein was replaced by an animal by-product mixture (i.e., replacement of 0, 25, 50, 75 and 100%). No differences were found among the five treatment groups in fish growth, dressing percentage, fillet quality, or gamete quality. Contrary to expectations, however, mineral analysis of fecal samples indicated that diets containing animal by-products were not less-polluting in terms of phosphorus levels.

Purdue University (Purdue) researchers found in the first year of this project that a fish meal-free diet containing soybean meal, corn gluten meal, and corn grain as the predominate ingredients could promote weight gains in rainbow trout within 90% of fish fed a control diet. In the second year, improvements were made in this diet. Lysine was identified as the first-limiting essential amino acid, meat meal was successfully incorporated into the diet, and a combination of canola and fish oils were found to be better than either lipid source alone. A commercial astaxanthin product successfully masked the yellow pigmentation in the muscle of trout. Fish fed any of the fish meal-free diets were preferred by a trained taste panel over filets from fish fed a commercial diet.

OBJECTIVE 2

University of Wisconsin-Madison (UW-Madison) investigators identified a physiological measure of stress that was well correlated with growth in rainbow trout--serum cortisol levels 3-hours following an acute handling stressor. Individual fish that consistently showed low 3-hour post-stress cortisol levels (i.e., fish that recovered rapidly from stress, defined as "low" fish) had a mean specific growth rate (SGR) of 0.54, as compared to a mean SGR of 0.41 in unselected fish. Fish with consistently high cortisol levels at 3-hours post-stress and a low SGR ("high" fish) were also identified. Selected fish were to be spawned in the autumn of 1995 and the offspring of selected and non-selected fish compared in terms of growth rates, stress responsiveness, and other indicators of performance. However, not enough selected individuals were available to complete the experiment, primarily because of a problem with tag retention. In December 1995, therefore, 160 two-year-old fish were obtained from Seven Pines Trout Hatchery to begin a new round of selection. All fish were bled three times over a six month period to identify both "low" and "high" individuals. This selection process was much more efficient than that used previously, since only one physiological endpoint (3-hour cortisol level) was measured (compared to the nine endpoints evaluated in the earlier selection process). By September 1996, five female and five male "low" fish, and nine female and five male "high" fish had been identified. Spawning started in early October 1996. Sperm from two selected "low" males chosen at random was used to fertilize eggs from each selected "low" female, and likewise for the "high" fish. Eggs and milt from brood stock chosen randomly from the original Seven Pines population were fertilized in an identical manner to serve as non-selected controls. Five groups of larval fish from each population ("low," "high," and control) will be reared for subsequent performance evaluations.

OBJECTIVE 3

In 1996, a ten-week production-scale field trail was performed at the Calamus State Fish Hatchery by University of Nebraska-Lincoln (UNL) researchers with help from personnel of the Nebraska Game and Parks Commission comparing the growth, performance, mortality rates, health, and stress responses of rainbow trout in raceways versus oxygen-supplemented cylindrical tanks. Six of the latter were each equipped with a sealed packed column supplied with oxygen, and assigned fingerling trout at a Piper rearing density of 0.45 or 0.9 (three tanks per treatment). Six raceways equipped with conventional packed columns were also each assigned fish at a Piper density index of 0.45 or 0.9 (three raceways per treatment). Turnover rates were kept constant between all four treatment groups. Parameters measured during the course of the study were dissolved oxygen, carbon dioxide, ammonia-nitrogen, pH, total dissolved gas pressure, P, and temperature. At the conclusion of the study, a stress challenge test and Goede health assessment were performed. Blood samples were collected and prepared for analyses of serum cortisol, glucose and chloride levels.

WORK PLANNED

MSU investigators anticipate completing all of their experiments by the end of February 1997. In 1997, UW-Madison investigators will be comparing the growth and performance of selected and control fish reared under identical conditions. The selected brood stock will also be kept and respawned in the fall of 1997 to evaluate the effects of the selection process on gamete quality as well as on subsequent offspring performance. UNL investigators will statistically evaluate the growth, production, Goede health-assessment, and water chemistry data collected during the 1996 field trial. The blood samples collected at the end of this field trial will be analyzed for serum cortisol, glucose, and chloride levels by UW-Madison investigators. The findings of all the Nebraska studies will then be compiled and submitted for publication in a peer-reviewed journal, and as part of a North Central Regional Aquaculture Center project termination report.

IMPACTS

- Trout diets devoid of fish meal can be used to produce marketable size rainbow trout, with no impact on fish quality. Basal diets can be formulated that use regionally available feed ingredients. Growout fish fed that diet exhibited feed conversion ratios of 1.0-1.1 when fed to satiation. Ingredient costs of the diet were 15% less than a standard commercial trout diet containing fish meal. Price comparisons were based on five year average commodity prices. Thus, as fish meal prices rise, alternative diets have been identified that result in similar weight gain of trout.
- The availability of rainbow trout strains with improved growth rate, feed conversion. and disease resistance will greatly improve the production efficiency of private and public fish hatcheries throughout the NCR. The availability of quality trout eggs from within the region will help reduce the need that regional trout farmers currently have for importing eggs from the west coast. The stress hyperresponsive, slow-growing fish identified in this study have characteristics typical of "wild" trout, and thus may have advantages for stocking recreational fisheries.
- The field trials conducted by UNL

investigators, both in the present and past salmonid projects, have verified that rainbow trout can be readily produced under both laboratory and practical rearing conditions at much higher rearing densities than is traditionally recommended. The Nebraska studies have also demonstrated that by using pure oxygen supplementation, trout can be produced in cylindrical tanks at as high a rearing density as in raceways - but at a significantly lower water turnover rate than is normally used in the latter. These findings are particularly important to trout farmers in the NCR who are often constrained by limitations in water and rearing space.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix A.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1994-95	$102,042	$103,987		$8,723[a]	$15,000[b]	$127,710	$229,752
1995-96	$97,958	$104,096		$9,867[a]		$113,963	$211,921
TOTAL	$200,000	$208,083		$18,590	$15,000	$241,673	$441,673

[a]University of Wisconsin Sea Grant
[b]International Collaborative Program for OSU to work jointly with the National Fisheries University of Pusan, Korea

AQUACULTURE DRUGS (INADs/NADAs)

Progress Report for the Period
September 1, 1992 to August 31, 1996

NCRAC FUNDING LEVEL: $17,000 (September 1, 1993 to August 31, 1996)

PARTICIPANTS:

Ted R. Batterson	Michigan State University	Michigan
Henry S. Parker	USDA/CSREES/PAPPP	Washington, DC
Robert K. Ringer	Michigan State University	Michigan
Rosalie A. Schnick	Michigan State University	Wisconsin

PROJECT OBJECTIVES

(1) Ensure effective communications among groups involved with Investigational New Animal Drug/New Animal Drug Applications (INADs/NADAs), including Canada.

(2) Serve as an information conduit between INAD/NADA applicants and the U.S. Food and Drug Administration's Center for Veterinary Medicine (CVM).

(3) Identify and encourage prospective INAD participants to become involved in specific investigational studies and NADA approval-related research.

(4) Seek the support and participation of pharmaceutical sponsors for INAD studies and NADAs and coordinate with INAD/NADA sponsors to achieve CVM approval more quickly.

(5) Guide prospective and current INAD holders on the format for INAD exemption requests and related submissions to CVM.

(6) Identify existing data and remaining data requirements for NADA approvals.

(7) Review, record, and provide information on the status of INADs and NADAs.

(8) Encourage and seek opportunities for consolidating the INAD/NADA applications.

(9) Coordinate educational efforts on aquaculture drugs as appropriate.

(10) Identify potential funding sources for INAD/NADA activities.

ANTICIPATED BENEFITS

Investigation and approval of safe therapeutic and production drugs for use by the aquaculture industry are one of the highest priorities currently facing the industry. At present, only a few approved compounds are available to the industry and further development of the aquaculture industry is severely constrained by a lack of approved drugs essential for treating more than 50 known aquaculture diseases. CVM has afforded the aquaculture industry throughout the U.S. with a "window of opportunity" to seek approval of legal drugs to be used in their production practices. The need for additional drugs is great, but securing data necessary to satisfy the requirements of CVM for drug approval is time consuming, costly, and procedures are rigorous. The INAD/NADA process is the one method that allows the industry to provide CVM with data on efficacy and also aids producers in their production practices.

Coordination and educational efforts directed toward potential INAD/NADA applicants will save time and effort for both the industry and CVM. The National Coordinator for Aquaculture INADs/ NADAs serves as a conduit between an INAD/NADA applicant and CVM. The National Coordinator helps to alleviate time demands on CVM staff, thus allowing more time to process a greater number of applications as well as increasing the breadth of research endeavors within the industry. The grouping of INAD applicants should help to alleviate redundancy, amalgamate efforts, and increase the amount of efficacy data, all of which should result in greater progress toward developing available, approved therapeutic and production drugs.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

In September 1992, Ringer, Professor Emeritus of Michigan State University, was hired on a part-time basis as National Coordinator for Aquaculture INAD Applications. He served in that capacity through August 31, 1994.

As National Coordinator for Aquaculture INADs Ringer participated with CVM in educational workshops on INAD procedures and requirements. These workshops were conducted throughout the U.S. This included workshops held in conjunction with the U.S. Trout Farmers Association, Boston Seafood Show, and Aquaculture Expo V in New Orleans. The workshop at the Boston Seafood Show was videotaped and is now available on cassette from the Northeastern Regional Aquaculture Center. In addition to the workshops, talks were presented on aquaculture drugs at the request of several organizations, including the World Aquaculture Society.

Ringer also helped in the preparation of a letter that CVM used in requesting disclosure information from those holding aquaculture INADs. By law, CVM cannot release any information about an INAD without such permission. A table containing information about these disclosures was made available to the general public. This included the names and addresses of the INAD holders as well as the drug and species of fish intended for use of the drug. It is intended that this table will be periodically updated after additional disclosure permissions have been obtained.

On May 15, 1995, Rosalie A. Schnick, recently retired Registration Officer from the National Biological Service's Upper Mississippi Science Center (UMSC), was hired on a three-quarter time basis as National Coordinator for Aquaculture New Animal Drug Applications (National NADA Coordinator). On May 15, 1996 her position was increased to a full-time basis.

As National NADA Coordinator, she organized and coordinated a major INAD/NADA workshop in November 1995 under sponsorship of CVM that led to increased communications between INAD coordinators, better coordination of the data generation for each drug, and consolidation of several INADs.

New INAD/NADA Sponsors

Schnick helped gain a new INAD/NADA

sponsor for amoxicillin (INAD #9659) and met with Vetrepharm Limited (United Kingdom) in May 1996 in Fordingham, UK, to discuss an action plan for the development of the INAD/NADA on their broad spectrum antibacterial product. Schnick also helped obtain and is working with INAD/NADA sponsors for hydrogen peroxide (microbicide, INAD #9671), luteinizing-hormone releasing hormone (spawning aid, INAD #9318), common carp pituitary (spawning aid, INAD #9728) and Aqui-S (anesthetic, INAD #9731).

<u>Progress on Therapeutic Drugs</u>

Schnick and representatives of the Upper Mississippi Science Center (UMSC), La Crosse, Wisconsin held a special session at the Midcontinent Warmwater Fish Culture Workshop in February 1996 to consider label claims and identify potential pivotal study sites for chloramine-T under the federal-state drug approval partnership program (a project of the International Association of Fish and Wildlife Agencies = IAFWA Project).

Based on residue and environmental data, CVM determined on July 11, 1996 that there are no human food or environmental safety concerns over the use of copper sulfate as a therapeutant, thus making approval relatively easy. Two meetings were held in July and August 1996 with a potential NADA sponsor and CVM to discuss the data requirements for approval and develop an action plan needed to obtain approval of copper sulfate as a therapeutant.

On July 18, 1996, CVM accepted the data and conclusions of a target animal safety study on the toxicity of formalin to warm- and coolwater fish eggs that was submitted along with a proposed formalin label by UMSC in December 1995. CVM will soon issue a notice in the Federal Register inviting sponsors to amend their labels to include the extended claims for both the fungicide (based on UMSC studies) and parasiticide uses (based on studies at Auburn University, Auburn, Alabama). These extensions of the formalin NADA to additional species will remove the need for INADs on formalin for these claims.

<u>Progress on Anesthetics</u>

Two meetings in June and August 1996 were held with representatives of Aqui-S, an anesthetic approved for use on fish in New Zealand to discuss the potential for development of Aqui-S in the United States. Aqui-S is approved in New Zealand with a zero withdrawal time and offers a potential alternative to benzocaine. UMSC decided to evaluate the comparative efficacy and regulatory requirements needed for approval on both benzocaine and Aqui-S. Work on benzocaine through the IAFWA Project has been put on hold until the new anesthetic, Aqui-S, can be evaluated. After an evaluation has been made on efficacy and regulatory requirements, UMSC will decide along with its state partners in the IAFWA Project and U.S. Fish and Wildlife Service whether to pursue Aqui-S or benzocaine for approval as an anesthetic/sedative.

<u>Progress on Hormones</u>

A meeting was held at CVM headquarters on April 11, 1996 with Stoller, users of common carp pituitary (CCP) and researchers to determine a course of action for gaining approval of CCP. As a follow-up to that meeting, CVM coordinated a conference call on May 15, 1996 that covered: (1) the identification of researchers and the design of target animal safety studies; (2) the writing of the environmental assessment through the National Research Support Program Number 7 (NRSP-7), and (3) potential funding sources of the target

animal safety studies.
The National NADA Coordinator contacted all the holders of disclosed INADs on human chorionic gonadotropin (hCG) at the urging of CVM to send all the data to the sponsor, Intervet, Inc., that was incorporated in a February 1996 Intervet submission to CVM. CVM ruled on February 12, 1996 that enrollment in an INAD will not be required to use hCG as a spawning aid. CVM will defer regulatory enforcement if used by or on order of a veterinarian. Any hCG product may be prescribed, but CVM strongly encourages the use of Intervet's product, Chorulon®.

Schnick worked with CVM, Auburn University, Rangen, Inc. and tilapia producers to develop INAD #9647 on 17α-methyltestosterone (MT) for tilapia (obtained January 25, 1996) and then worked to obtain authorization from CVM and permission from Auburn University to allow the use of MT on yellow perch under Auburn's INAD (obtained February 22, 1996). The North Central Regional Aquaculture Center (NCRAC) provided $25,000 to Southern Illinois University-Carbondale and the UW-Madison to conduct a target animal safety study on MT with walleye and has requested $5,000 for Auburn University to conduct a literature review of the environmental data on MT for NADA submission to CVM.

Progress on the IAFWA Project

Several meetings were held at UMSC in May and June 1996 to review the whole IAFWA Project related to the following topics on each of the 10 study plans: (1) remaining data requirements; (2) tasks and jobs; (3) assignments for each job; (4) a time table for completing each assigned task; (5) budget projections by study plan and year; (6) budget shortfalls for the original IAFWA Project; and (7) assessment of the potential products at the end of the IAFWA Project. UMSC has reprogrammed its effort and direction under the IAFWA Project due to changes in requirements and circumstances for benzocaine, chloramine-T, hydrogen peroxide, oxytetracycline, and sarafloxacin. Efforts were made to save the entire IAFWA Project during government downsizing and budget reductions. Based on the assessment of the remaining data requirements and the funds available, UMSC determined that the IAFWA Project was short a total of $1.4 million and two years of effort.

WORK PLANNED

The National NADA Coordinator developed an action plan that centers on coordinating all drugs of high priority for aquaculture toward NADAs through the INAD process. In particular, Schnick plans to: (1) develop a major initiative on amoxicillin to obtain approval for its use as a broad spectrum antibacterial in all fishes; (2) determine the potential of fumagillin to control or prevent whirling disease in salmonids and hamburger gill disease in catfish and pursue an INAD/NADA if feasible; (3) help determine the potential for approval of two anesthetics, benzocaine and Aqui-S; (4) assist the efforts of the NRSP-7 to complete the approval process for sarafloxacin to control enteric septicemia in channel catfish; (5) identify potential funding sources for INAD/NADA activities; and (6) continue to coordinate efforts to obtain approvals for all 19 high priority aquaculture drugs.

Several meetings and workshops are planned that will benefit aquaculture drug approvals. A meeting will be held in Kansas City, Missouri on November 7-8, 1996 to discuss the protocols and select the pivotal study sites for chloramine-T. The NADA Coordinator arranged the agenda and speakers for a special session entitled "Partnerships for aquaculture drug approvals: models for success" to be held at World Aquaculture '97, Seattle, Washington, February 19-23, 1997. An International Harmonization Workshop for Aquaculture Drugs/Biologics is scheduled as part of World Aquaculture '97 to be held in Seattle, Washington on February 24, 1997 that will create an international forum, identify potential actions, and develop implementation strategies in cooperation with other countries to facilitate approvals of aquaculture drugs.

IMPACTS

Establishment of the National NADA Coordinator position in May 1995 has resulted in coordination, consolidation, and increased involvement in the INAD/NADA process on 17 of the 19 high priority aquaculture drugs and activities on two new drugs of interest to aquaculture. Six new INAD/NADA sponsors have initiated new INADs and progress has been made toward unified efforts on existing and new INADs/NADAs.

This enhanced coordination will help gain extensions and expansions of approved NADAs and gain approvals for new NADAs. In fact, data on formalin have recently been accepted by CVM and amended NADAs are expected soon from the three current NADA sponsors of formalin.

PUBLICATIONS, MANUSCRIPTS, PAPERS PRESENTED, AND REPORTS

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1992-93				$17,000[a]		$17,000	$17,000
1993-94	$2,000			$12,180[b]	$4,000[c]	$16,180	$18,180
1994-95	$5,000		$23,750[d]	$70,000[e]	$10,000[f]	$103,750	$108,750
1995-96	$10,000		$20,000[g]	$56,920[h]	$5,000[i]	$81,920	$91,920
TOTAL	$17,000		$43,750	$156,100	$19,000	$218,850	$235,850

[a]USDA funding through a Cooperative Agreement with NCRAC

[b]USDA funding through a Cooperative Agreement with NCRAC ($8,500) and FDA's Office of Seafood Safety ($3,680)

[c]Northeastern Regional Aquaculture Center ($2,000) and Southern Regional Aquaculture Center ($2,000)

[d]American Pet Products Manufacturers Association ($7,500), American Veterinary Medical Association ($10,000), Catfish Farmers of America ($2,000), Fish Health Section of AFS ($1,000), Florida Tropical Fish Farm Association, Inc. ($500), Natchez Animal Supply ($1,000), National Aquaculture Council ($1,000), and Striped Bass and Hybrid Producers Association ($250)

[e]USDA funding through a Cooperative Agreement with NCRAC ($23,000), CVM ($22,000), and USDI/NBS International Association of Fish and Wildlife Agencies Project ($25,000)

[f]Northeastern Regional Aquaculture Center ($5,000) and the Center for Tropical and Subtropical Regional Aquaculture ($5,000)

[g]American Pet Products Manufacturers Association ($1,000), Catfish Farmers of America ($10,000), Fish Health Section of AFS ($1,000), Florida Tropical Fish Farms Association, Inc. ($1,500), Striped Bass & Hybrid Producers Association ($1,500), Simaron Fresh Water Fish, Inc. ($2,500), and Abbott Laboratories ($2,500)

[h]CVM ($18,400) and USDI/NBS International Association of Fish and Wildlife Agencies Project ($28,520)

[i]Center for Tropical and Subtropical Aquaculture ($5,000)

APPENDIX A

EXTENSION

NCRAC Extension Fact Sheet Series

Garling, D.L. 1992. Making plans for commercial aquaculture in the North Central Region. NCRAC Fact Sheet Series #101, NCRAC Publications Office, Iowa State University, Ames.

Harding, L.M., C.P. Clouse, R.C. Summerfelt, and J.E. Morris. 1992. Pond culture of walleye fingerlings. NCRAC Fact Sheet Series #102, NCRAC Publications Office, Iowa State University, Ames.

Kohler, S.T., and D.A. Selock. 1992. Choosing an organizational structure for your aquaculture business. NCRAC Fact Sheet Series #103, NCRAC Publications Office, Iowa State University, Ames.

Swann, L. 1992. Transportation of fish in bags. NCRAC Fact Sheet Series #104, NCRAC Publications Office, Iowa State University, Ames.

Swann, L. 1992. Use and application of salt in aquaculture. NCRAC Fact Sheet Series #105, NCRAC Publications Office, Iowa State University, Ames.

Morris, J.E. 1993. Pond culture of channel catfish in the North Central Region. NCRAC Fact Sheet Series #106, NCRAC Publications Office, Iowa State University, Ames.

Morris, J.E. In review. Pond culture of hybrid striped bass fingerlings. NCRAC Fact Sheet Series #107, NCRAC Publications Office, Iowa State University, Ames.

Cain, K., and D. Garling. 1993. Trout culture in the North Central Region. NCRAC Fact Sheet Series #108, NCRAC Publications Office, Iowa State University, Ames.

Mittelmark, J. In review. Fish health management. NCRAC Fact Sheet Series #109, NCRAC Publications Office, Iowa State University, Ames.

Rosscup Riepe, J. In review. Managing feed costs: Limiting delivered price paid. NCRAC Fact Sheet Series #110, NCRAC Publications Office, Iowa State University, Ames.

Rosscup Riepe, J. In press. Costs of pond production of yellow perch in the North Central Region, 1994. NCRAC Fact Sheet Series #111, NCRAC Publications Office, Iowa State University, Ames.

Morris, J.E., and C.C. Kohler. In review. Pond culture of hybrid striped bass fingerlings in the North Central Region. NCRAC Fact Sheet Series, NCRAC Publications Office, Iowa State University, Ames.

NCRAC Technical Bulletin Series

Thomas, S.K., R.M. Sullivan, R.L Vertrees, and D.W. Floyd. 1992. Aquaculture law in the north central states: a digest of state statutes pertaining to the production and marketing of aquacultural products. NCRAC Technical Bulletin Series #101, NCRAC Publications Office, Iowa State University, Ames.

Swann, L. 1992. A basic overview of aquaculture: history, water quality, types of aquaculture, production methods. NCRAC Technical Bulletin Series #102, NCRAC Publications Office, Iowa State University, Ames.

Kinnunen, R.E. 1992. North Central Region 1990 salmonid egg and fingerling purchases, production, and sales. NCRAC Technical Bulletin Series #103, NCRAC Publications Office, Iowa State University, Ames.

Hushak, L.J., C.F. Cole, and D.P. Gleckler. 1993. Survey of wholesale and retail buyers in the six southern states of the North Central Region. NCRAC Technical Bulletin Series #104, NCRAC Publications Office, Iowa State University, Ames.

Lichtkoppler, F.P. 1993. Factors to consider in establishing a successful aquaculture business in the North Central Region. NCRAC Technical Bulletin Series #106, NCRAC Publications Office, Iowa State University, Ames.

Swann, L., and J. Rosscup Riepe. 1994. Niche marketing your aquaculture products. NCRAC Technical Bulletin Series #107, NCRAC Publications Office, Iowa State University, Ames.

Tetzlaff, B., and R. Heidinger. In review. Basic principles of biofiltration and system design. NCRAC Technical Bulletin Series #109, NCRAC Publications Office, Iowa State University, Ames.

Swann, L., J. Morris, and D. Selock. 1995. Cage culture in the midwest. NCRAC Technical Bulletin Series #110, NCRAC Publications Office, Iowa State University, Ames.

Rosscup Riepe, J. In press. Enterprise budgets for yellow perch production in cases and ponds in the North Central Region, 1994. NCRAC Technical Bulletin Series #111, NCRAC Publications Office, Iowa State University, Ames.

Brown, P., and J. Gunderson. In press. Culture potential of selected crayfishes in the North Central Region. NCRAC Technical Bulletin Series #112, NCRAC Publications Office, Iowa State University, Ames.

NCRAC Video Series

Swann, L. 1992. Something fishy: hybrid striped bass in cages. VHS format, 12 min. NCRAC Video Series #101, NCRAC Publications Office, Iowa State University, Ames.

Pierce, R., R. Henderson, and K. Neils. Aquacultural marketing: a practical guide for fish producers. 1995. VSH format, 19 min. NCRAC Video Series #102, NCRAC Publications Office, Iowa State University, Ames.

Swann, L., editor. 1993. Investing in freshwater aquaculture. VHS format, 120 min. NCRAC Video Series #103, NCRAC Publications Office, Iowa State University, Ames.

Kayes, T.B. In production. Spawning and propagating yellow perch. VHS format, 45 min. NCRAC Video Series, NCRAC Publications Office, Iowa State University, Ames.

NCRAC Culture Series

Summerfelt, R., editor. 1996. Walleye culture manual. NCRAC Culture Series #101, NCRAC Publications Office, Iowa State University, Ames.

Other Videos

Kayes, T.B., and K. Mathiesen, editors. 1994. Investing in freshwater aquaculture: a reprise (part I). VHS format, 38 min. Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln.

Kayes, T.B., and K. Mathiesen, editors. 1994. Investing in freshwater aquaculture: a reprise (part II). VHS format, 41 min. Cooperative Extension. Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln.

Situation and Outlook Report

Hushak, L.J. 1993. North Central Regional aquaculture industry situation and outlook report, volume 1 (revised October 1993). NCRAC Publications Office, Iowa State University, Ames.

Workshops and Conferences

Salmonid Culture, East Lansing, Michigan, March 23-24, 1990. (Donald L. Garling)

Midwest Regional Cage Fish Culture Workshop, Jasper, Indiana, August 24-25, 1990. (LaDon Swann)

Aquaculture Leader Training for Great Lakes Sea Grant Extension Agents, Manitowoc, Wisconsin, October 23, 1990. (David J. Landkamer and LaDon Swann)

Regional Workshop of Commercial Fish Culture Using Water Reuse Systems, Normal, Illinois, November 2-3, 1990. (LaDon Swann)

North Central Aquaculture Conference, Kalamazoo, Michigan, March 18-21, 1991. (Donald L. Garling, Lead; David J. Landkamer, Joseph E. Morris and Ronald Kinnunen, Steering Committee)

Crayfish Symposium, Carbondale, Illinois, March 23-24, 1991. (Daniel A. Selock and Christopher C. Kohler)

Fish Transportation Workshops, Marion, Illinois, April 6, 1991 and West Lafayette, Indiana, April 20, 1991. (LaDon Swann and Daniel A. Selock)

Regional Workshop on Commercial Fish Culture Using Water Recirculating Systems, Normal, Illinois, November 15-16, 1991. (LaDon Swann)

National Aquaculture Extension Workshop, Ferndale, Arkansas, March 3-7, 1992. (Joseph E. Morris, Steering Committee)

Regional Workshop on Commercial Fish Culture Using Water Recirculating Systems, Normal, Illinois, November 19-20, 1992. (LaDon Swann)

In-Service Training for CES and Sea Grant Personnel, Gretna, Nebraska, February 9, 1993. (Terrence B. Kayes and Joseph E. Morris)

Aquaculture Leader Training, Alexandria, Minnesota, March 6, 1993. (Jeffrey L. Gunderson and Joseph E. Morris)

Investing in Freshwater Aquaculture, Satellite Videoconference, Purdue University, April 10, 1993. (LaDon Swann)

National Extension Wildlife and Fisheries Workshop, Kansas City, Missouri, April 29-May 2, 1993. (Joseph E. Morris)

Commercial Aquaculture Recirculation Systems, Piketon, Ohio, July 10, 1993.

(James E. Ebeling)

Yellow Perch and Hybrid Striped Bass Aquaculture Workshop, Piketon, Ohio, July 9, 1994. (James E. Ebeling and Christopher C. Kohler)

Workshop on Getting Started in Commercial Aquaculture Raising Crayfish and Yellow Perch, Jasper, Indiana, October 14-15, 1994. (LaDon Swann)

Aquaculture in the Age of the Information Highway. Special session, World Aquaculture Society, San Diego, California, February 7, 1995. (LaDon Swann)

North Central Aquaculture Conference, Minneapolis, Minnesota, February 17-18, 1995. (Jeffrey L. Gunderson, Lead; Fred P. Binkowski, Donald L. Garling, Terrence B. Kayes, Ronald E. Kinnunen, Joseph E. Morris, and LaDon Swann, Steering Committee)

Walleye Culture Workshop, Minneapolis, Minnesota, February 17-18, 1995. (Jeffrey L. Gunderson)

Aquaculture in the Age of the Information Highway. Multimedia session, 18 month meeting of the Sea Grant Great Lakes Network, Niagra Falls, Ontario, May 6, 1995. (LaDon Swann)

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Yellow Perch Aquaculture Workshop, Spring Lake, Michigan, June 15-16, 1995. (Donald L. Garling)

Rainbow Trout Production: Indoors/Outdoors, Piketon, Ohio, July 8, 1995. (James E. Ebeling)

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APPENDIX A

APPENDIX B

Summary Report
North Central Regional Aquaculture Center Review
February 23-25, 1996

At the request of the Board of Directors of the North Central Regional Aquaculture Center (NCRAC), a programmatic review of the NCRAC was held on the campus of Michigan State University, East Lansing, Michigan on February 23-25, 1996. The Review was held in conjunction with the Annual Program Planning Meeting--a joint meeting of the Board of Directors (BOD), Industry Advisory Council (IAC) and Technical Committee (TC). Members of the Review Team were as follows:

George W. Lewis, The University of Georgia
Randy MacMillan, Clear Springs Foods, Inc., Buhl, ID.
Richard L. Noble, North Carolina State University
Sandra Ristow, Washington State University.

Team efforts were assisted by USDA personnel, Meryl C. Broussard and Gary L. Jensen, serving in facilitator roles.

The goal of the review was to assess the overall effectiveness of the NCRAC program in planning, developing, implementing and evaluating its collaborative programs. Emphasis was placed on the priority-setting process, particularly with regard to industry needs; project development and implementation, particularly the effectiveness of team-building and team performance relative to the priority needs; and the process for reviewing progress, outputs and impacts. In addition, the team identified one general topic for further elaboration.

Efficiency and effectiveness of the review were significantly enhanced by well-prepared background materials, centralized facilities in the Kellogg Hotel and Conference Center, rapid response to special needs during the review, and a strong spirit of cooperation by NCRAC participants at all levels. Ted Batterson, Joe Morris and Liz Bartels of the NCRAC put forth a commendable effort in effecting a successful review.

BACKGROUND AND CURRENT STATUS

The NCRAC is one of five regional aquaculture centers established as a result of the Food and Security Act of 1985. Having been established as the last of the five regional aquaculture centers, NCRAC was able to capitalize on the experience of the other RACs in its initial organization. NCRAC geographically encompasses 12 states.

Administrative responsibility for NCRAC is shared between Michigan State University and Iowa State University. The

Director, Ted Batterson, and Executive Secretary, Liz Bartels, are housed at Michigan State University. The NCRAC Office for Publications and Extension Administration, staffed by the Associate Director, Joe Morris, and Secretary, Glenda Dike, is located at Iowa State University.

The primary policy-making body of NCRAC is the BOD, comprised of two representatives of the IAC, a representative of State Agricultural Experiment Stations, a representative of State Cooperative Extension Services, a member from a non-Land Grant university, and one representative each from Michigan State and Iowa State Universities. Chairs of the TC-Research and TC-Extension are ex-officio members of the BOD.

Recommendations for program priorities are developed by the IAC, with input from the TC. The BOD then selects priority areas for development of project outlines and specifies intended funding levels. At the Annual Program Planning Meeting, problem statements and objectives are developed jointly by IAC and TC representatives. After BOD approval of problem statements and prioritized objectives, projects typically are developed through a workshop approach, convened via broadly-distributed notice through the region. The Work Group submits a project outline to the Director, who obtains peer review from inside and outside the region, and from both industry and academic reviewers. At the following year's Annual Program Planning Meeting, the BOD makes final decisions on projects and funding levels.

The Annual Program Planning Meeting also serves as a forum for evaluating progress on active projects. Results of all continuing and terminating projects are reported, and implications for the aquaculture industry discussed.

From an annual budget of approximately $750,000, NCRAC has funded 36 projects over the past 8 years. Duration of projects typically is 1 or 2 years. A species approach frequently has been taken in research projects, which typically have an extension component incorporated. In addition, projects with entirely extension objectives have continuously been in place, thereby providing continuity in technology transfer.

MISSION AND VISION

The mission of the Regional Aquaculture Centers (RACs) is to support aquaculture research, development, demonstration and extension education to enhance viable and profitable U.S. aquaculture production which will benefit consumers, producers, service industries and the American economy. Projects, driven by industry needs and developed using a multi-state team approach, are to directly impact commercial development in the region. Interregional coordination occurs through the National Coordinating Council for Aquaculture.

The NCRAC has developed fully in accord with this mission. Despite a diversity of aquaculture industries in the region, NCRAC has stimulated participation by a reasonable cross-section of producers; despite limited numbers of aquaculture scientists in the region, NCRAC has mobilized researchers and extension specialists to work together to solve industry problems, to transfer technology to producers, and to educate the general public about aquaculture.

As NCRAC has implemented the mission of the RAC program, it has focused on scientific solutions to production problems, including transfer of results to producers. For a region characterized by a fledgling aquaculture industry, NCRAC's focus on production, including economics and marketing, has been appropriate. The Center has chosen to place priority on species approaches, thereby moving steadily toward firmly establishing industries based on those particular species. Through time, recognition of common needs across species-based industries has led to a gradual incorporation of projects which take a disciplinary approach, with broad application to aquaculture in the region.

Although participation by representatives of the greater aquaculture industry infrastructure has only minimally occurred, and NCRAC has not directed its efforts explicitly beyond producers, NCRAC is having a more comprehensive effect on the industry. During the review, references were made to programs addressing the feed production component (relative to regional feedstuffs), processing facilities (relative to implementation of HACCP), financial institutions (relative to lending), educational institutions (relative to meeting workforce needs), consumers (relative to acceptability f new products) and the general public (relative to potentials for entering the industry and to understanding the environmental aspects of aquaculture).

NCRAC also has chosen to serve in a leadership role in interregional coordination. Linkages have been established with other RACs to develop projects to address issues of broad concern, including aquaculture effluents and therapeutic drugs.

EVALUATION OF PROGRAM DEVELOPMENT, IMPLEMENTATION, AND REVIEW

The review team was impressed with the high level of organization of NCRAC. Explicit, efficient procedures have been implemented and are well-understood. Cooperation between individuals and complementarity of activities in the two administrative offices is excellent, thereby facilitating smooth, efficient operation of the Center.

Enthusiasm for aquaculture and the role of NCRAC is pervasive. Despite the diversity of interests and approaches of individuals involved in NCRAC, a high level of mutual respect and spirit of cooperation was evident within and among the administrative entities of the Center. Throughout, there was a strong commitment to enhance the aquaculture industry in the region. In addition, participants in every aspect of the Center indicated that NCRAC had benefitted the region by bringing together industry and academic leaders, and by stimulating collaborative efforts among universities and between research and extension functions.

The Annual Program Planning Meeting was an ideal setting for conduct of this review. All participants were cooperative with the Review Team and open with their comments, thereby ensuring the critical evaluation that was sought by all.

I. Priority Setting

One of the most critical functions of a USDA RAC is the determination of activity priorities. Limited funding and human resources, and regional individuality highlight the need for such activity prioritization. Since the fundamental mission of the RACs is to support US aquaculture through research, development, demonstration, and extension education, the process of activity prioritization is crucial if the needs are to be met. This can be difficult for a region as diverse as the North Central region.

The NCRAC prioritization process is well described in the recently completed Operations Manual. The manual describes how the process is supposed to function. How well that process is actually executed may vary. The NCRAC is to be complimented for its execution of activity prioritization and delineation of funding levels for each activity. While opportunity for improvement exists, we find that industry-defined needs (insofar as the industry is able to conceptualize those needs) are largely addressed.

One of the most admirable features of the NCRAC is its emphasis on continual self-improvement. This dynamic effort has resulted in structural and procedural practices that can ensure effective prioritization, all in spite of the diversity of fish species interests and levels of aquaculture development. The BOD is well balanced and particularly sensitive to industry's articulated needs. The recent addition to the BOD of a second IAC member provides keen evidence of their concern. During the conduct of BOD business, deferral of action until the IAC members were present provides additional evidence of concern. The NCRAC administrative staff extensively contacts the regional scientific community attempting to gain broad scientific participation and, hence, insight. The academic research/extension community plays a key role in helping the industry to define its specific needs and the practical prioritization of those needs. Yet, it is the aquaculture industry itself, through the IAC, that ultimately recommends specific prioritization.

The composition of the IAC is key to ensuring broad industry representation. The IAC is composed of specific representatives, usually the presidents, of each state's aquaculture trade association. At-large membership is also available for those states without a state aquaculture association. This complex creates an opportunity for excellent industry need identification and activity prioritization. The IAC may want to further capitalize on this opportunity to increase the effectiveness of the IAC. Indeed, the IAC has already recognized some additional steps they should take.

The IAC carries significant responsibility for identifying needs and setting industry priorities. The RACs are, after all, industry driven. The NCRAC structure and policies already in place ensure that industry priorities will be addressed. The key is to correctly and fairly identify those needs. Diverse representation on the IAC, TC, BOD and the external project review process prior to funding helps ensure that prioritizations are reasonable. It is incumbent on the IAC to ensure that they correctly discover and then represent the industry needs.

The IAC should consider being more proactive. Better internal organization, preparation for the Annual Program Planning Meeting and organized communication could serve them well. The NCRAC administrative staff may be able to assist in this effort. To their credit, the IAC has already recognized some needs in this area. The IAC, in any type of planning, may find it beneficial to include at least one TC-R/TC-E member in their deliberations. These individuals can assist the IAC to better identify researchable arenas. Each state aquaculture association may want to periodically survey its membership (following NCRAC guidance) to fairly determine industry needs. The survey could be done by mail or during annual meetings.

One of the most pressing needs of the regional aquaculture industry and NCRAC is to develop a long range (5-10 year) vision and plan. Both short and long term projects are valuable to any business or group of businesses. Short term projects (2 year) are well represented in the NCRAC project schedule. While difficult for an industry coalition (the IAC) still in its formal formative stages to develop, a long term plan on how to utilize the resources provided through NCRAC could be extremely advantageous. To facilitate such long range goals, the NCRAC BOD may want to consider a policy for making longer term funding available to the scientific community. A long range plan or even the process of developing one may also help the IAC, TC and BOD clearly define what criteria they will use to actually set priorities. The recent failure of the Alternate Species proposal to maintain consistent IAC and BOD support illustrates, at least in part, the need for a clear vision. While the RAC program must be flexible, it may nevertheless benefit from a more deliberate, directed process provided by a long range plan.

A long range plan has additional benefits. Such a plan can be a useful guide for the research and extension communities as they seek extramural funding. Competitive grants sought by the scientific community can be leveraged by the limited NCRAC dollars. A long range plan may also help the limited extension personnel budget their activities. Long range plans could also help address needs voiced by IAC members who are not in a majority position--an issue that obviously requires some internal (IAC) consideration. Since multiple species needs have been identified, it may be advantageous to consider horizontal systems research (across species boundaries). We do, however, recognize that systems research with diverse species is difficult. The process of examining such a possibility may help lead to a long range plan.

Several additional approaches could strengthen the ability of the IAC to identify industry concerns and define research objectives. To facilitate IAC activities, it is imperative that members be knowledgeable of previous NCRAC work, extra-regional activities and the needs of their industry. A program should be considered to familiarize IAC members with previous NCRAC actions and extra-regional activities. This is particularly important since there appears to be considerable turnover in IAC membership. Some IAC members also report lack of access to NCRAC literature. Perhaps an updated list of NCRAC publications could be made available to the industry representatives for use in determining status of knowledge on perceived needs. Additionally, considerable species-specific research activity has occurred through other RAC programs. Updates of these activities could be provided to the IAC. Interregional information exchange opportunities are probable in marketing, feeds, salmonids, and catfish. As part of this program, close relationship of the IAC members with the TC-R/TC-E is essential. Project workshops and industry liaisons on projects already facilitate this relationship. IAC programs could be attended by TC representatives. Any activity that fosters IAC and TC interactions should be encouraged. It is important, especially for long term objectives, that researchers appreciate factors that motivate the industry (e.g. the market) and that the IAC membership understand factors that motivate scientists. Appreciation of project progress would be further enhanced by a time line with objectives and outcome for each project area (e.g., species) from inception to proposed completion.

The IAC, TC and BOD recognize the need for addressing various public policy issues and for seeking analysis of economic potential. Assistance from marketing and economic specialists in several project areas has already been identified as critical. Should regional expertise not be forthcoming, consideration should be given to interregional efforts. Recognition of food safety issues, fish therapeutant needs and environmental stewardship
responsibilities appear to be well recognized by the entire regional aquaculture community and is a consideration in their activity prioritization.

The NCRAC is to be complemented for developing activities addressing a diversity of species. Balanced by fiscal realities, they are willing to consider new species for potential aquaculture development. The Review Team noted, however, that despite Situation and Outlook data which indicated significant numbers of sportfish and baitfish producers, no emphasis has been placed on addressing needs of these components of the industry.

Additional opportunities for interaction with other regions through interregional efforts and with other players, while not a priority, is nevertheless an important ingredient in the NCRAC program. Linkage with, and integration of, Sea Grant Extension agents in NCRAC is significant. The efforts of NCRAC and NRAC in an interregional waste management effort attests to the commitment of NCRAC to the needs of industry and to interregional projects.

II. Project Development and Implementation

NCRAC has a well-defined procedure for development of problem statements and objectives which should ensure relevance to industry needs. Although the definition of objectives occurs at the Annual Program Planning Meeting, and involves both industry an academic inputs, some difficulty was evident in translating problems into clear, achievable objectives. This has created some problems for both the BOD and the subsequent Work Group. Nevertheless, for previous and existing projects, research and extension project objectives are clearly stated and seem to be consistent with industry needs. Members of the IAC provide input and are present as objectives are defined. The IAC seems to be representative of the region's diverse industry, and it is assumed their input is reflective of the region's needs. IAC members should be encouraged to work with their respective state extension specialists for assistance in contacting producers for input into NCRAC programs. Extension also has a presence on each Work Group, and extension's input on research objectives helps to reflect the needs of the industry and ensure that research information is delivered into the hands of the targeted clientele.

NCRAC does an excellent job in providing opportunities for interaction of IAC, TC and BOD members in refining and prioritizing objectives. The review team observed the BOD and IAC interacting, leading to suggestions for improving the effectiveness of IAC's involvement with NCRAC.

Project objectives seem to be relevant to priorities established by NCRAC. However, the review team questions the two-year funding cycle. It appears that a three- or four-year term of support for a project would allow more comprehensive projects with more in-depth objectives.

NCRAC organizational procedures are excellent for facilitating the appropriate inputs for the development of Center projects. Notice of project workshops is disseminated widely in the region to all identified potential participating entities. Although some weeding out of possible participants occurs in the workshop deliberations, the process is inclusionary rather than exclusionary. In some cases, needed expertise appears to be unavailable within the region. When such circumstances occur, consideration should be given to looking beyond the boundaries of the region to appropriately address the objectives. The review team noted that project proposals are reviewed both internally and externally to the region, and these reviews are also used in project refinement.

The overall quality of science and technical merit of the research and extension projects is excellent. Project results have value to the region's aquaculture industry as well as making contribution to aquaculture science. The review team questions the NCRAC policy of predominantly funding two-year species projects. This appears to be perpetuating ongoing, long-term project areas that do not have definable end points. The review team recommends funding longer term projects that are more comprehensive in nature and that the Center consider a disciplinary systems approach to projects when common needs exist across species. Such an approach would foster new collaborations, identify and consolidate critical masses of disciplinary expertise and facilitate the application of common principles to addressing problems of the various components of the region's aquaculture industries. The Center should also consider developing projects based upon the immediate and existing market economic opportunities of the region.

In all ongoing projects the review team observed a healthy balance and communication between research scientists, extension specialists, and industry representatives. NCRAC does an excellent job of facilitating these interactions. Producers have frequently served as collaborators in conduct of project components at their facilities. Extension components are now built into projects from the start, and are viewed as an integral ongoing part of projects rather than a terminal activity. Research scientists routinely include technology transfer as a part of their activities, and are included by extension personnel in the numerous outreach programs of the Center. The review team recommends NCRAC consider providing clearer guidance to industry representatives as to their possible roles in project work groups and in the conduct of projects. It was observed that some industry participants were unclear as to their roles and responsibilities in project development and implementation.

NCRAC does an excellent job in organizing, facilitating, and providing resources for Center projects. The BOD provides a firm, but flexible commitment of funds prior to project development. The newly revised Operations Manual is a clear, precise reference for the administration of the Center and management of projects. The guidance of the Director and Associate Director complements the activities of the various NCRAC entities involved in project development and implementation, and facilitates completion of tasks according to schedule. The BOD is giving attention to the need for some assurance of continuity in funding for project areas, both to attract participation by scientists from some disciplines, and to assist in projection of endpoints. As indicated earlier, long-term planning and longer term project funding would alleviate some of the uncertainty about continuity of support.

All NCRAC-funded programs are successful in leveraging additional outside funds to support Center projects. As indicated by the annual reports, various sources of funding are being consolidated to attack problems of the region's industry. It is obvious that NCRAC projects have helped to provide seed monies to cooperating institutions to help enhance their aquaculture research, teaching and service programs. Project reports indicate that substantial in-kind contributions are also provided by producers who cooperate in projects. That support should somehow be quantified and included in total project funding. Another leveraging that has obviously occurred as a result of NCRAC activities has been that of growth in institutional expertise, especially that in extension FTE's in the region.

The work group approach is effectively meeting the needs and objectives of the Center, although there is widespread sympathy within the TC (academic community) to modify the current procedure. As the work group approach evolves, some minor problems are being resolved through interactions of research scientists, extension specialists and industry representatives, and by attention of the BOD. The review team recognizes that the work group approach may not be satisfactory for every project developed by the Center, that some modification of the current Work Group procedures may be needed, and that some NCRAC projects may be better served by a request for proposals (as is sometimes used).

III. Performance Review

Two major means are provided to assure the appropriate review and evaluation of the various projects administered under the Center. These include presentations at the Annual Program Planning Meeting by the workgroup chairpersons which summarize the major accomplishments of their respective projects, and a booklet, The NCRAC Progress Report, which is assembled annually by the center. The reports contained in the booklet highlight each ongoing project and present a final report for each terminated project. Each report contains: (1) objectives which have been addressed by the respective project, (2) principal accomplishments, (3) specific impacts, (4) recommended follow-up activities and (5) a notation containing the NCRAC funding and additional funding which has been garnered by the project from other federal, state and private sources. Project outputs in the form of publications, videos, reports, and technology transfer meetings are appended to the Report.

Reports by the chairpersons of each workgroup at the Annual

Program Planning Meeting underscore the work which has been accomplished during the previous year or during the entire life of a project (in the case of a termination of the project). This presentation informs the combined audience (BOD, university researchers and administrators, extension personnel, members of the IAC and other interested observers) of the scientific impacts, associated extension work and the possible practical value of each project .

Overall, the review panel was impressed by the thoroughness of the reports presented in the booklet and the excellent concise presentations by the workgroup chairs. Nevertheless, it was unclear how the commends made during discussions following the presentations would be incorporated into deliberations of the Work Group.

The research accomplishments in the Annual Report are followed by an appendix containing a myriad of internally and externally reviewed extension publications, videos, refereed journal articles, situation and outlooks and reports, and workshops and conferences attributed to each project. NCRAC is to be commended, in particular, for their extension efforts, considering that there are only four extension FTEs serving aquaculture in this vast multi-state area . Serving 5000 clients at workshops and delivering 15,000 publications is indeed a remarkable feat. In the 1996 report, the center lists 21 refereed publications with a large number of manuscripts forthcoming.

The research accomplishments are appropriate for the stated objectives and for the group of scientists assigned to the various projects. Projects appear to be bringing forth results pertinent to the emerging and established species being cultured in the region, including yellow perch, sunfish, walleye, tilapia and salmonids. Various practical applications of technologies directed towards industry are appearing from the various projects, e.g. sperm extenders and cryopreservation techniques for hybrid striped bass, and methods for the production of more economical fish meal-free diets. Walleye and sunfish culture manuals are also underway which highlight the respective emerging technologies and the various modifications of culture introduced by members of the workgroups.

The review team did not observe any formal method of tracking projects. This may change with a more active involvement of the IAC members in the workgroups. An IAC member is appointed to each work group; however, it should be noted that no clear direction is given to the IAC member as to expected involvement with the Work Group. Also, an Administrative Advisor may be appointed to the Work Group, if applicable. The review team recommends the appointment of an Administrative Advisor to all work groups as an "ex officio" member to help track project progress and development.

Despite the presentation of project progress reports during the annual Program Planning Meeting, there was no evidence of a structured interim review of active projects. There was no indication of specific project problems, e.g., deviation from project objectives, schedules or needs to modify project budgets. The review team recommends that project work groups meet during the Annual Program Planning Meeting to discuss work in progress and any specific needs or problems related to their projects. As an alternative, these meetings may be held prior to the annual meeting so that a program needing redirection can be effectively discussed by the TC, IAC and/or BOD at their annual meeting.

NCRAC does an excellent job in communicating to the industry. An extension component is built into every Center project and extension representation is required in every work group. Research and extension professionals have good communication in all aspects of project development and completion. The Center's associate director is being used as an effective clearinghouse for the development of various guides, manuals, circulars and other publications designed to report resarch and related educational materials to the industry. It should also be noted that the Center is effectively using electronic media (AquaNIC-web page at Purdue University) to deliver timely information to industry clientele and other professionals. However, IAC members indicated their need to learn how to better access information resources.

For four years, the Center has been publishing the NCRAC Journal, an attractive widely disseminated popular publication, which describes highlights of projects in practical terminology. The Journal introduces readers to key personnel, announces the forthcoming RFP's, tradeshows and conferences and gives pertinent regional and national news concerning aquaculture.

Reports tend to emphasize progress and results, with little emphasis on impacts, i.e., the enhancement of aquaculture, indicated in the NCRAC mission. Although a number of impacts of NCRAC were mentioned in various contexts during the review, no formalized assessment of impacts was noted. Considering the small but diverse industry in the region, this may be a timely, but difficult, task to accomplish. The review team did not observe any consideration of present or future development of methods to measure tangible impacts of NCRAC programs. We recommend that the NCRAC BOD request that the TC, with IAC input, develop a Work Group and allocate necessary resources to develop an effective process to evaluate present and future program impacts.

Attention needs to be given to termination of project areas as priority objectives are attained, and to make room for new project areas to be funded. Currently, projects in NCRAC have a duration of two years. Then, providing the IAC sees a need, the projects are extended for an appropriate time, usually another two years, to accomplish newly assigned objectives. These project extensions have been particularly valuable for establishing new culture practices regarding sunfish and walleye. Apparently, for these species, a temporary endpoint has been reached, although it is unclear whether these endpoints were anticipated up front, either in terms of results or timeline.

The Review Team is somewhat concerned that the current "species approach" to regional projects does not afford clearly defined endpoints to a project. The review team has recognized that there are common and overlapping problems and research needs cutting across the current "species projects" including, e.g., recirculation systems, fry production, and nutrition. It may be more efficient to use these topics as project headings. One possible result of the adoption of this nomenclature may be that the endpoints to these projects may be more easily defined. Under the present system, most projects do not have a method to evaluate achievement of desired outcomes.

GENERAL ISSUE 1: ENSURING FULL REPRESENTATION

The relatively small size of the aquaculture industry and the small number of aquaculture scientists in the region pose a challenge to ensure that participants in NCRAC are representative of their constituents and not be entrained by the status quo. Rotating terms of appointment have been adopted, which help to provide an influx of new people and ideas. This seems to be working particularly well for the IAC; however new IAC members need orientation to assist them in becoming effective immediately. Especially those representatives of state aquaculture associations need to seek out ideas from their constituents and blend them with their own to serve in a two-way communication. In the case of TC membership, it appears that a shortage of FTEs leads to frequent reappointment of individuals, mostly with biological, production expertise. Although such appointments provide continuity, they also tend to maintain specific project emphases. Efforts should be undertaken to be more comprehensive in kinds of expertise appointed to the TC, especially on the research side. In the case of the BOD, which is comprised in part by administrators who are not directly involved in aquaculture, turnover seems to result in some loss of continuity and understanding of current status of work. Therefore, the NCRAC administrative directors have particular responsibility for maintaining institutional memory, and consequently have much implicit authority. In all cases (IAC, TC and BOD), care must be taken to give broad industry needs priority over personal/institutional agendas.

CONCLUSION

The NCRAC has succeeded in many ways, and the aquaculture industries, as well as the academic institutions of the region, have benefitted from its eight-year existence. It has mobilized and integrated a diverse work force in the region, and is effectively achieving its goals and those of the RAC program as it responds to the needs of the industry. The structure of the Annual Program Planning Meeting strongly facilitates interaction among the TC, IAC and BOD. Through strong leadership in the administrative offices, a high level of organization has been adopted by NCRAC, leading to effective and continually improving operations. The BOD has assumed a strong role in establishment and implementation of policy, while being attentive to the voices of industry and academic components of the Center. In its deliberations, the BOD should give more attention to long-range planning, and weight the relative benefits of species approaches and disciplinary (systems) approaches to addressing the needs of industry. By more fully identifying comprehensive benefits to the industry, it should be possible to measure the impacts as well as the outputs of the various projects. Incorporation of outreach in every dimension of NCRAC activities has ensured that information dissemination takes place and technology is transferred rapidly and effectively to industry’s and society’s benefit.